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Military Sketching *and* Map Reading

—Grieves

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MILITARY SKETCHING

AND

MAP READING

BY

CAPT. LOREN C. GRIEVES
INFANTRY

THIRD EDITION
REVISED and ENLARGED

UNIV. OF CALIFORNIA

WASHINGTON
UNITED STATES INFANTRY ASSOCIATION
1917

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PREFACE

In writing this book an effort has been made to produce a text-book on Military Sketching and Map Reading meeting the requirements of the curriculum prescribed for educational institutions operating under the provisions of the War Department, also to meet the requirements prescribed in the examination of candidates for commissions in the Regular Army and the Reserve Officer's Training Corps, and to provide a suitable course for the officers of the National Guard, and thus standardize the instruction throughout the service. In view of the above, attention is invited to War Department orders prescribing text-books.

It has been the aim to produce a suitable text-book at the minimum price, free from all extraneous matter and yet completely fulfilling the requirements.

The author acknowledges with thanks the valuable assistance rendered by Captain A. W. Bjornstad in co-ordinating the subject matter of the text to meet the requirements of the various branches of the military establishment.

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INTRODUCTION

The first duty of the instructor is to eradicate from the mind of the student the mistaken idea of many that this is a difficult subject. Many have the idea that one must possess artistic abilities in order to become proficient. That is not true. Simply master the basic principles and apply them. Some may be able to turn in neater and more artistic sketches than others, but the reader is looking for facts, and, if the facts are shown, the sketch answers the purpose.

The subject, in so far as this text is concerned, is divided into two parts. Part I treats of Military Map Reading, or, the classification of maps; the natural and artificial objects represented on the map; methods of interpretation and military uses of maps. Part II treats of Military Topographical Sketching, or the means and methods employed in making military road and area sketches, and the reports pertaining to them.

It is enjoined upon the instructor to employ the means and methods suggested, and to anticipate the requirements of each lesson as to equipment. Large classes may be instructed successfully by one instructor if the right methods are pursued. The suggestions given in the Appendix which pertains to training camps apply in so far as the equipment is concerned to the work in organizations and educational institutions.

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PART I

LESSON I

LENGTH OF PACE OR STRIDE

Before taking up the subject of scales, the student should determine the length of his pace or stride.

An accurately measured course of at least one thousand yards should be selected. A thousand yards on the target range will answer the purpose, or, if a target range is not available, a course may be measured, preferably on turf rather than on a macadamized road or sidewalk. While pacing, one should take an easy, natural, and uniform gait. This is important as there is always a tendency on the part of the beginner to consider pacing and his natural gait as entirely distinct, which usually results in his first scale of paces or strides being too long. This may be obviated by pacing a sufficiently long course several times (four times is suggested), first impressing upon the student's mind the necessity of taking a natural and uniform gait.

Let us assume that each student has paced the course four times, and that his four results of pacing a course 1,000 yards long are:

1118 paces.
1109 "
1120 "
1117 "

Total 4464 paces.

4464 ÷ 4 = 1116 paces (average number of his paces for 1,000 yards).

To determine the length of his pace in inches:

1,000 yards = 36,000 inches.
36,000 ÷ 1116 = 32.2 inches, the length of his pace.

Before computing the length of his pace, each student should present his results of pacing to the instructor for verification, and, if any wide discrepancies exist, the student should be required to pace the course again.

To avoid error in pacing, the student should keep a record

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of the number of paces by making a mark for each 100 paces. A pace tally may be used if available. A hand instrument known as a "Tallying Register" may be used in recording the number of strides, if a scale of strides is desired.

To accurately determine the length of pace or stride of each student, without doubt, will occupy the time available for the first lesson, and the construction of scales will be taken up in the next lesson.

REVIEW

Explain, as to a beginner, exactly how to determine the length of one's pace or stride.

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LESSON II

INDIVIDUAL SCALE OF PACES OR STRIDES, READING SCALES

Having determined the length of our pace or stride, let us now consider the subject of scales of maps. It is very clear that the ground and all of the objects upon it cannot be represented as large on the map as they actually are. They must be reduced in size. In other words, any distance on the map is a certain fixed part of the corresponding distance on the ground, and this relation between map distance and ground distance is called the scale of the map.

The scale should be no larger than is necessary to bring out all of the required details. For example, it has been found that the scale, 3 inches = 1 mile (meaning that 3 inches on the map represents 1 mile on the ground), is the proper scale for "Road Sketches." It gives just enough room to insert all of the details of military importance, while, if we were to use the scale, 1 inch = 1 mile, for "Road Sketches," there would not be enough room, and by using the scale 6 inches = 1 mile, we would burden ourselves and those reading the map with an unnecessary amount of paper.

There are three ways in which the scale of a map may be represented.

1st. A plain statement, as, for example, 3 inches equals 1 mile.

2nd. Represented by a fraction. To determine the fraction representing any scale, as 3 inches = 1 mile, let the map distance be the numerator and the ground distance the denominator, BOTH TERMS OF THE FRACTION BEING OF THE SAME DENOMINATION, then reduce the fraction so that the numerator will be unity, as, for example:

$$\frac{\text{3 inches on map}}{\text{1 mile on ground}} = \frac{\text{3 inches}}{\text{63360 inches}} = \frac{1}{21120} = \text{Representative Fraction (abbreviated R. F.)}$$

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3rd. Graphically, in which the scale is actually represented on the map, or on a ruler by a line divided into equal parts, each division being marked by the distance which it represents on the ground.

There are two kinds of graphical scales: one for making the map, called a working scale, and one for reading the map, called a reading scale. If the same units of measure were used for both map making and map reading, one scale would answer for both purposes; but this is seldom the case, as we may obtain our distances in terms of paces or strides of various lengths depending upon the individual, while the party reading the map necessarily must have the distances expressed in terms of well-known units such as yards or miles.

TO CONSTRUCT A WORKING SCALE OF PACES

Let us assume that a student has paced a course of a thousand yards four times with the following results:

1st result, 1118 paces.
2nd result, 1109 paces.
3rd result, 1120 paces.
4th result, 1117 paces.

He wishes to construct a working scale, 3 inches on the scale representing 1 mile on the ground. To do so he should proceed as follows:

1st. Find the length of his pace.

2nd. Find how many of his paces will be represented by one inch on the map.

3rd. Find the length in inches of his working scale.

4th. Construct the scale.

1st

TO FIND THE LENGTH OF HIS PACE

(See Lesson I)

2nd

TO FIND HOW MANY OF HIS PACES WILL BE REPRESENTED BY ONE INCH ON THE MAP

3 inches on the map = 63360 inches on the ground.
1 inch on the map = 21120 inches on the ground.
21,120 ÷ 32 = 660 of his paces.

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3rd

TO FIND THE LENGTH IN INCHES OF A CONVENIENT WORKING SCALE REPRESENTING SAY 2,400 PACES

660 paces = 1 inch.
2,400 ÷ 660 = 3.63 inches, length of scale.

TO CONSTRUCT THE SCALE

Lay off the line *AB* (Fig. 1), 3.63 inches long, which represents 2,400 paces. Divide this line into 24 equal divisions representing 100 paces each. Divide the first one of these divisions on the left into five equal parts representing 20 paces each. Transfer these divisions to a suitable straight-edge ruler and the working scale is completed. Working scales of 1″, 6″, and 12″ to the mile may be constructed in a similar manner, also working scales of strides.

To divide the line *AB* (Fig. 1) into 24 equal divisions, lay off any line *AC* that can be conveniently divided into 24 equal parts. Draw a straight line connecting *B* and *C*, then draw lines parallel to *BC* as shown in the figure. These lines will divide *AB* into 24 equal divisions of 100 paces each. Use the same method for the divisions representing 20 paces.

The ruler shown in Fig. 2 is the most suitable for sketching. It is made of a triangular, straight-edged piece of hard wood. A hole 3/8 inch in diameter and 2 inches deep may be bored into each end of the ruler and filled with lead to give it weight. This form of ruler furnishes a well-defined sighting line, and is the most convenient of any working scale yet devised. The material may be obtained by the instructor and cut into 6-inch strips, and, if practicable, filled with lead; or they may be obtained at a nominal price from the Book Department, Army Service Schools, providing the Book Department is furnished with the necessary data as to the various lengths of paces or strides desired.

After determining the length of your pace or stride, the working scale may be transferred to the ruler directly

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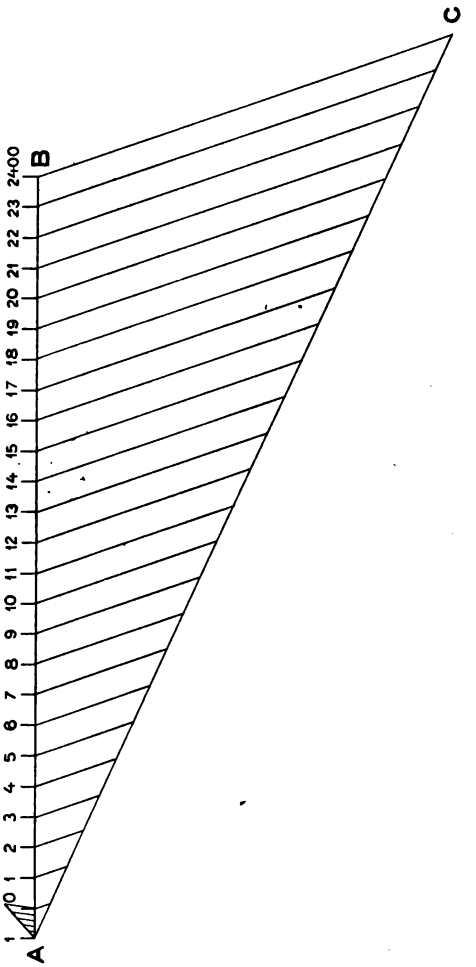

FIG. 1.

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from the consolidated scales shown in Fig. 3 by placing the edge of the ruler on the proper line or interpolating between lines. This is sometimes found to be more practicable with certain non-commissioned officers than attempting to require them to solve the problems.

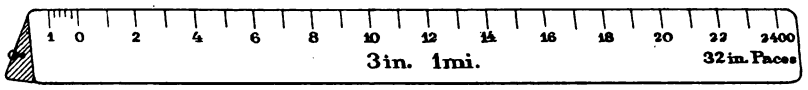

FIG. 2

TO CONSTRUCT A READING SCALE OF YARDS

After a sketch has been completed, you wish to place upon the sketch a reading scale of yards so that any other person may be able to read distances correctly from your sketch.

Assume that the scale of your sketch is 3 inches = 1 mile, or 1 inch = 21120 inches = 596.66 yards. Say that you desire a reading scale that reads to 3,000 yards.

$3{,}000 \div 596.66 = 5.11$ inches, the length of your scale.

With a box-wood scale, lay off a line 5.11 inches long, and by the method explained in Fig. 1 divide it into 30 equal parts, or any other number of equal parts, and your reading scale of yards is completed.

REVIEW

1. What is meant by the scale of a map?
2. In what three ways may scales be represented?
3. Six inches on a certain map represents 1 mile on the ground. Represent the scale of this map by the three methods.
4. Construct a working scale of paces for your own use for making a map on a scale $3'' = 1$ mile, also a working scale of paces for your own use for making a map on a scale of $6'' = 1$ mile.
5. How may the above working scales be converted into working scales of strides?

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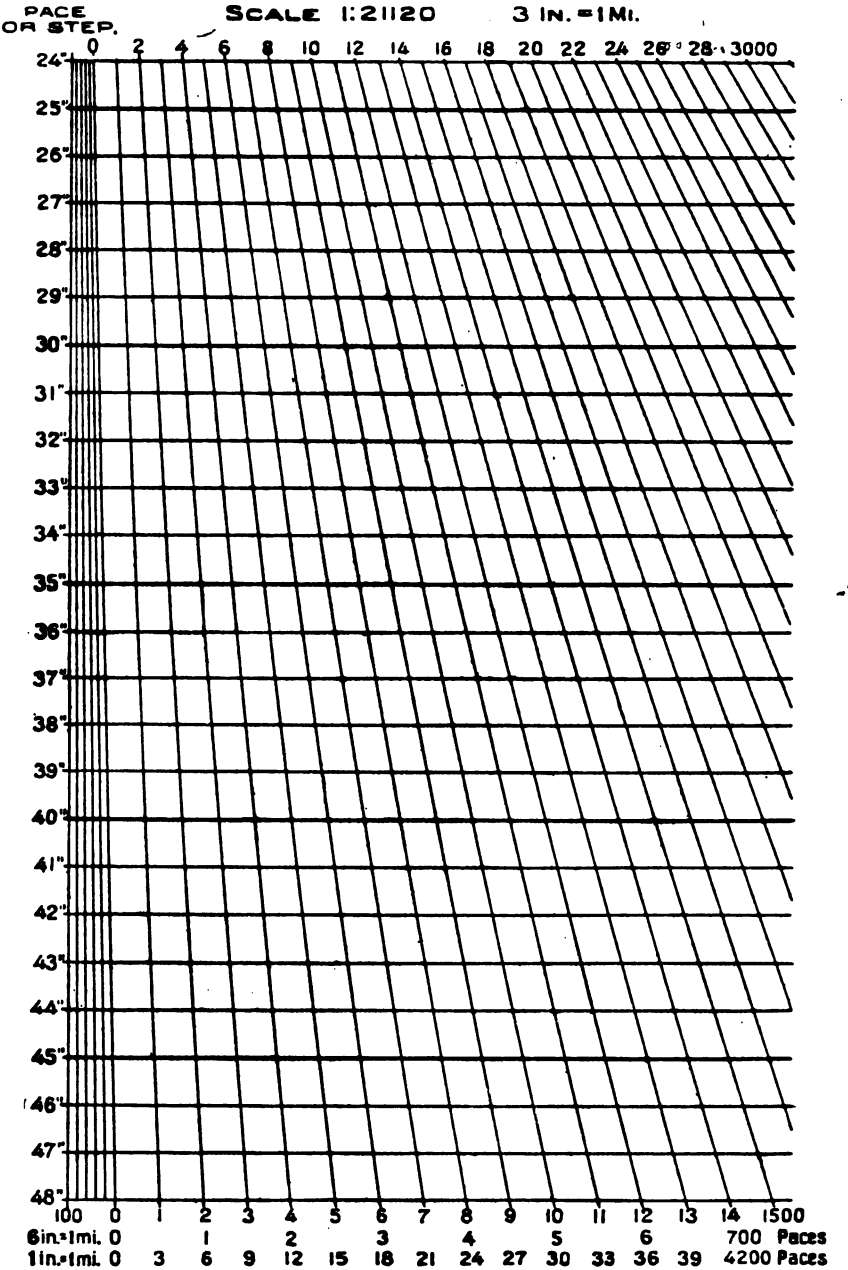

FIG. 3

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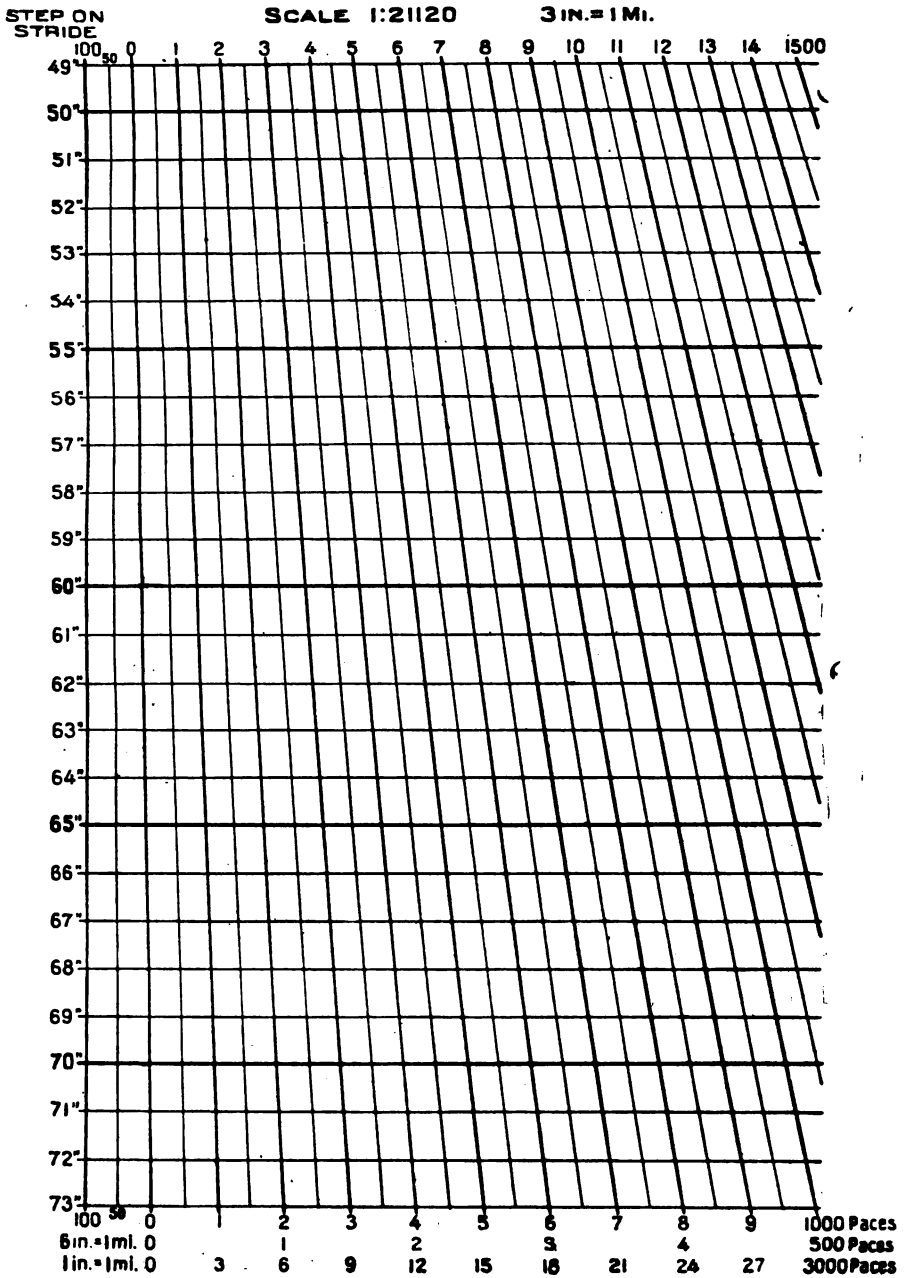

FIG. 8

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LESSON III

SOLUTION OF SCALE PROBLEMS

Problem No. 1

Scale of minutes to be used by mounted sketcher.

A sketcher's horse trots 1 mile in 8 minutes. Construct a scale of minutes for an R. F. of $\frac{1}{21120}$.

Solution:

8 minutes = 63360 inches.
1 minute = 7920 inches.
1 inch on map = 21120 inches on the ground.
$\frac{21120}{7920} = 2\frac{2}{3}$ minutes to cover one inch on map.
Let us construct a scale 6″ long.
$2\frac{2}{3} \times 6 = 16$ minutes to cover 6 inches.

Construct the scale by dividing a line 6 inches long into 16 equal parts, each part representing the distance traveled in one minute. Divide the space on the left into 4 equal parts giving the distance traveled in a quarter of a minute.

Problem No. 2

Foreign Maps

You are given a foreign map, scale, 1 centimeter = 1 Kilometer.

(*a*) Required, the R. F.

Solution:

Simply reduce 1 Kilometer to centimeters, and we have the R. F. $\frac{1}{100,000}$.

(*b*) How many inches to the mile in this scale?

Rule: To determine the number of inches to the mile of any R. F., divide 63360 by the denominator of the R. F.

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PROBLEM NO. 3

Foreign Maps

You are given a foreign map with a reading scale only. By measuring the reading scale, you find that 1 Kilometer = .92 inch. What is the R. F. of the map?

Solution:

1 KM. = 1,000 meters.
1 meter = 39.37 inches.
1 KM. = 39370 inches.
.92 inch on map = 39370 inches on the ground.

$$\frac{.92}{39370} = \frac{1}{42793} = \text{R. F.}$$

PROBLEM NO. 4

Map of Local Terrain with no Scale

To Determine the R. F.

Measure the distance between two points on the ground that are located on the map, then measure the map distance between the two points. Let the map distance be the numerator and the ground distance the denominator, BOTH BEING REPRESENTED IN THE SAME DENOMINATION. Reduce the fraction so that the numerator is unity and you have the R. F.

PROBLEM NO. 5

Relation of Scale to Area of Maps

Rule

To change the area of a map, multiply each of its linear dimensions by the square root of the change.

Example:

A map 12″ by 20″ is to be reduced to $\frac{1}{4}$ of its present area,

$\sqrt{\frac{1}{4}}\,12'' = 6''$.

$\sqrt{\frac{1}{4}}\,20'' = 10''$.

So it is seen that $6'' \times 10''$ are the reduced dimensions.

Also, a map $12'' \times 20''$ is to be enlarged to 4 times its present area.

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Applying the same rule, we find that the new dimensions are 24″×40″.

PROBLEM NO. 6

Correction of Erroneous Scales

You are directed to make a road sketch, scale 3″=1 mile. You use a working scale of 32″ paces. Later you find that your pace is actually 30″. What is the R. F. of the sketch actually made?

Solution:

If your pace had actually been 32″ long, the R. F., of course, would have been $\frac{1}{21120}$. The result of your shorter pace is the enlargement of the scale of the map, that is, a R. F. with a smaller denominator by $\frac{30}{32}$, making $\frac{1}{19800}$ the proper R. F.

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LESSON IV

MISCELLANEOUS SCALE PROBLEMS

1. Construct a working scale of paces for a map on the scale of 12″ = 1 mile, 110 paces being equal to 100 yards.

2. A sketcher's horse trots a mile in 7 minutes. Construct a scale of minutes and quarter minutes for a R. F. of $\frac{1}{10560}$.

3. A foreign map is reproduced on a scale of $\frac{1}{100,000}$.

(*a*) Construct a reading scale to show 10 miles on the map.

(*b*) Construct a reading scale to show 10 Kilometers. (1 Meter equals 39.37 inches.)

4. Your pace is 32″ long. You are given a map of local terrain which has no scale. Two points on the ground which are located on the map have a ground distance of 4,000 of your paces. The map distance is 6.3 inches. What is the R. F. of the map?

5. You are given a French map with a reading scale only. By measuring the reading scale, you find that 1 Kilometer = .76 inch. What is the R. F. of the map?

6. The dimensions of a map with a R. F. of $\frac{1}{63,360}$ is 6″ by 8″;

What will be the dimensions of the map of a R. F. of $\frac{1}{10,560}$? How much is its area increased?

7. You are directed to make a position sketch, scale 6″ = 1 mile. You use a working scale of 64″ strides. Later you find that your stride is actually 60″. What is the R. F. of the sketch actually made?

8. Draw a reading scale of yards for a map 15 by 18 inches to show an area of 6 square miles.

9. Our geological maps have a R. F. of $\frac{1}{62,500}$.

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Construct a reading scale of miles, halves, and quarters. One inch on our geological maps equals how many yards?

10. Compare the scales of various maps, such as our geological maps, maps of your city, geographical maps of states, county maps, construction maps, etc.

Always note the scale of a map before attempting to read the map.

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LESSON V

ORIENTATION, DISTANCE, AND DIRECTION

In the practical use of a map in the field, the next step, after determining its scale, is to "Orient" the map.

In order to compare the map with the ground that it represents, we must first see that the directions on the map and on the ground coincide. This is called "Orienting the map."

All complete maps have both the magnetic and true meridian indicated. The true meridian is a straight line joining the observer's position and the north pole of the earth. The magnetic meridian is a straight line that coincides in direction with the magnetic needle of the compass at the observer's position. The directions of the needle at different places on the earth's surface converge approximately toward the magnetic poles of the earth. These poles do not coincide with the poles of the earth's axis, and therefore the magnetic and true meridians do not generally coincide.

The angle between the magnetic and true meridian at any place is called the "Declination of the needle" for that place.

There is a certain irregular line on the earth's surface at all points of which the true and magnetic meridians coincide and the declination is zero. This line is called the "agonic" line. In the United States it passes in a southeasterly direction from Michigan through intervening states to South Carolina. The agonic line is not permanent, but is slowly moving westward. At all points in the United States east of the agonic line, the north end of the needle inclines to the west of the true meridian. To the west of the agonic line the needle inclines to the east of the true meridian.

Isogonic lines are lines joining points of the same declination of the needle. As the agonic and isogonic lines are gradually changing, maps should always have the true as well as the magnetic meridian indicated.

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There are a few simple methods of determining the true meridian (true north and south line), with a degree of accuracy sufficient for military sketching and map reading. For an accurate instrumental survey, an observation on Polaris (North Star) should be taken. This is not included in the text, as it properly comes under the head of advanced surveying.

First Method

By means of the North Star.—Without instruments, it can be determined approximately by placing two cords, with weights attached, in line with the star. The cords should be about 12 feet apart, and to see the forward one, it will be necessary to throw a light upon it. This line can readily be prolonged by daylight.

Second Method

By aid of the sun and plumb-bob (see Fig. 4).—On a level piece of ground lean a pole toward the north, and rest it in a crotch made by two sticks as shown. Suspend a weight from the end of the pole so that it nearly touches the ground; then, about an hour before noon, attach a string to a peg driven directly under the weight, and, with a sharpened stick attached to the other end of the string, describe an arc with a radius equal to the distance from the peg to the shadow of the tip of the pole. Drive a peg on the arc where the shadow of the tip of the pole rested. About an hour after noon watch the shadow of the tip as it approaches the eastern side of the arc, and drive another peg where it crosses. By means of a tape or string, find the middle point of the straight line joining the last two pegs mentioned. A straight line joining this middle point and the peg under the weight will be in the true meridian. Place a pole about a hundred yards in prolongation of this line, and with the compass sight back on the tip of the inclined pole, and the declination will be obtained.

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Third Method

By aid of the watch and sun.—Lay the watch on some level surface and revolve it until the hour hand points directly under the sun. Then by reference to the divisions

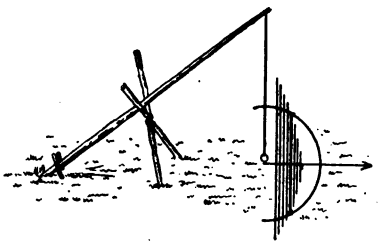

FIG. 4

on the dial, determine a point on it midway between the hour hand and twelve o'clock. A line through this point and the pivot of the hands will be approximately in the true meridian. (See Fig. 5.)

The operation of pointing the hour hand directly under the sun is made easy by casting the shadow of a vertical

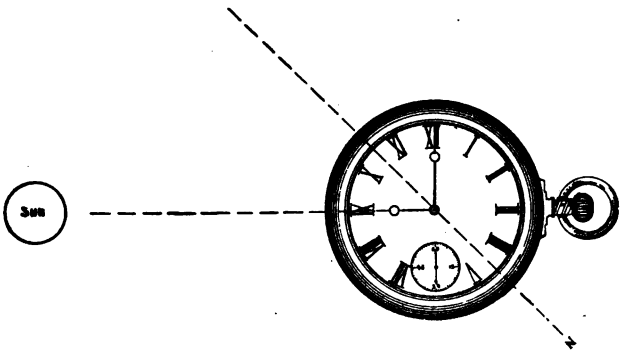

FIG. 5

straight stick across the face of the watch and then bringing the hour hand into this shadow.

The watch method will not answer during certain seasons in the tropics when the sun passes directly overhead.

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There is also another slight error due to the fact that in some sections there is a difference of half an hour between standard and sun time.

ORIENTING THE MAP

As heretofore stated, all complete maps have both the true and the magnetic meridian indicated. However, it is assumed that you have found the declination of the needle for your particular locality, so, if either the true or the magnetic meridian be given, the other can be readily determined.

First Method

When the map has the magnetic meridian marked on it: Place the compass on the map, so that the needle pivot rests on the magnetic meridian; revolve the map until the north end of the needle and the magnetic meridian point in the same direction, whereupon the map is oriented.

Suppose that only the true meridian is given on the map. Knowing the declination of the needle, construct a magnetic meridian and proceed as above.

Second Method

Suppose that neither the magnetic nor the true meridian is indicated on the map.

(*a*) Take position on the ground corresponding to some point on the map. Identify another point on the map that you can see on the ground. Join the two map positions by a straight line. Hold the map so that this line points toward the distant point seen on the ground, whereupon the map is oriented.

(*b*) Place yourself on the line of any two points visible on the ground and plotted on the map, rotate the map until the line joining the two points on the map points towards the two points on the ground, whereupon the map is oriented.

(*c*) Observation, co-ordinating map with the various visible terrain features.

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TO LOCATE YOUR MAP POSITION

First Method

After the map is oriented by the compass:

Sight along the rule at an object on the ground at the same time keeping the rule on the plotted position of this object on the map. Draw a line toward your body. Find another point on the ground that is plotted on the map and repeat the process. The intersection of the two lines is your map position. The two points selected should be so located that the angle formed at the intersection of the lines should be not less than 30 degrees nor greater than 120 degrees, otherwise the two intersecting lines are so nearly parallel that it is difficult to locate the exact point of intersection.

Second Method

If the map has been oriented by means of a straight line drawn between two map points, then it will be necessary to draw but one line from the object on the ground, and the intersection of this line with the line already on the map will be your location on the map.

Third Method

Observation.

MAP DISTANCES

Knowing the scale of our map and having oriented it, we should now be able to determine from the map the distance between objects on the ground and the direction of one from another.

We will first consider converting map distance into ground distance. Every complete map has a reading scale of some well-known unit as yards or miles, so all that is necessary to determine the ground distance between points on the map is to apply the reading scale to the map distance or the map distance to the reading scale.

There are several simple methods of taking distances from the map:

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First Method

Suppose that you have no reading scale except the one printed on the map. If such is the case, apply a piece of straight-edged paper to the distance between the two points to be measured. Mark the distance on the paper, and apply the paper to the reading scale of the map, or copy off the reading scale on a piece of paper and apply the paper to the map.

Second Method

A scale of inches may be applied to the distance between the two points to be measured, then multiply the number of inches between the two points by the number of miles per inch given on the map. (*Caution:* do not confuse the terms—"miles per inch," and "inches per mile.")

Third Method

The Geological Survey maps made on a scale of 1-62,500 are much used by the army, but as there is a difference of but about 1 per cent between these maps and maps made on the scale of 1-inch equals 1 mile, the 1-inch reading scale is sufficiently accurate for most purposes.

Fourth Method

It is often necessary to take off distances from the map in terms of one's paces or strides. To do so, simply apply your scale of paces for 1, 3, or 6 inches to the mile to maps of those scales, and for maps of 2, 4, or 5, or any other whole number not represented on your scale of paces, apply your 1-inch scale of paces and divide the result by two, four, or five as the case may be.

Fifth Method

Map Measurer.—A small instrument so constructed that it may be rolled over the surface of the map, and will record on a dial the distance passed over. Complete instructions for its use are given with each instrument,

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This instrument is especially valuable for use in map problems and war games.

MAP DIRECTIONS

As the captain consults his chart and compass in guiding his ship, so must the soldier consult his map and compass in traveling through unknown regions.

The usual style of box compass or other small compasses has the four cardinal points, N., E., S., and W. (North, East, South, and West), marked on its surface, and a circle graduated in degrees reading zero, clockwise around to 360 degrees, beginning and ending at N. In order to travel by the compass, one must be able to convert map directions into compass directions; in other words, we must be able to determine the MAGNETIC AZIMUTH of any line.

By the Magnetic Azimuth of a line is meant the horizontal angle that the line makes with the compass needle measuring from the north point clockwise around the circle. The True Azimuth is measured in the same direction from the north point of the True Meridian (true north and south line).

A protractor is an instrument for measuring and plotting angles. A protractor is usually so graduated that it is laid on the east side of the meridian through the plotted position for plotting angles from zero to 180 degrees, and from 180 degrees to 360 degrees the protractor is placed on the west side of the meridian.

To illustrate—you are at the point *A*, Fig. 6, and you wish to obtain the magnetic azimuth of the line *AB*. Draw a line *AC* through *A* parallel to the magnetic north and south line. Lay your protractor along *AC*, the center of the protractor at *A*. (The center of the protractor is indicated by an arrow point.) Read the number of degrees between *AC* and *AB*. It is found to be 63 degrees, which is the magnetic azimuth of the line *AB*.

Then suppose that you are at *A*, and wish to proceed in the direction of *B*. Simply hold the compass so that

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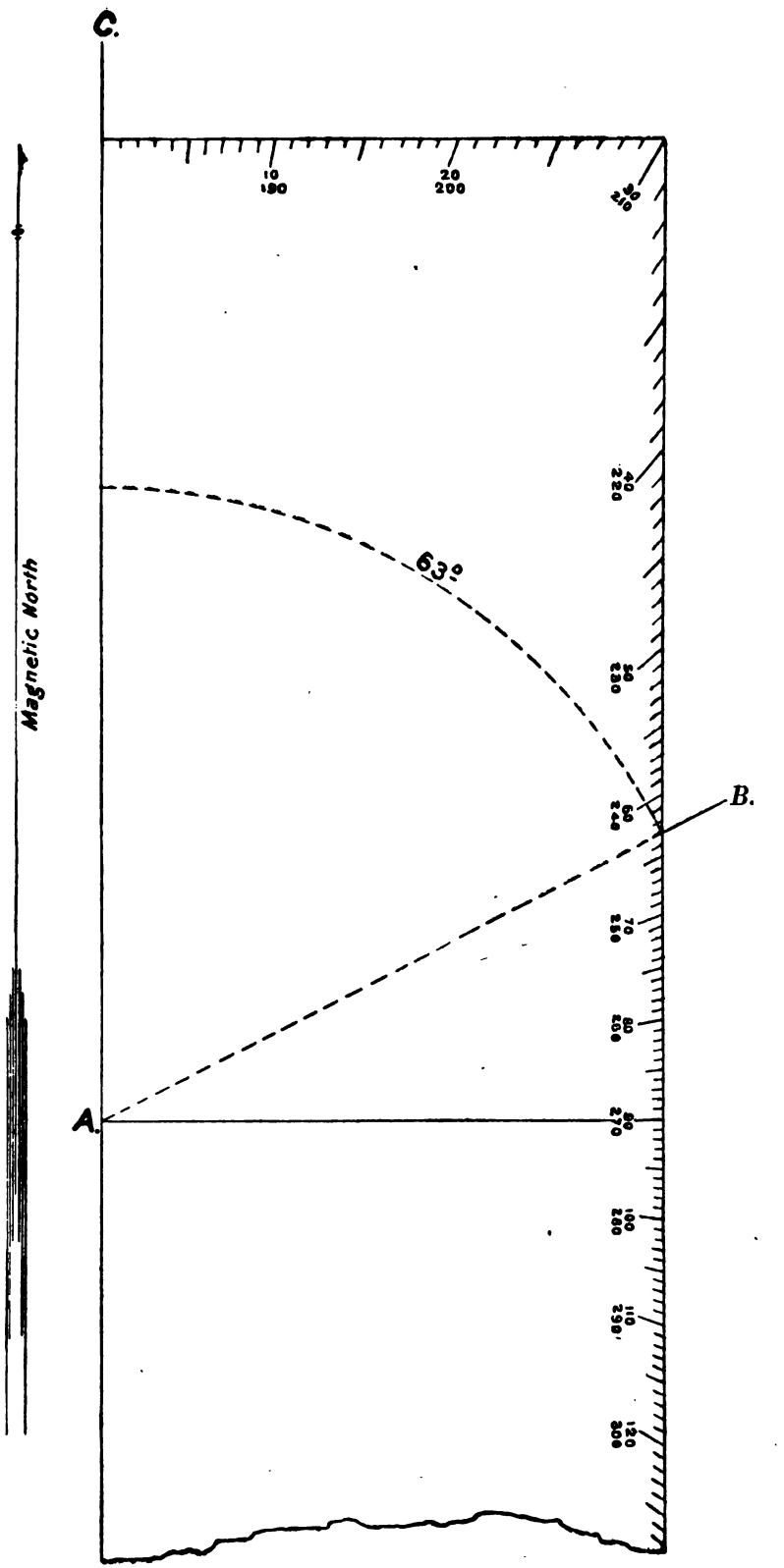

Fig. 6

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the needle is at *N*, then follow in prolongation of a line drawn through the pivot of the needle and the 63-degree point. The course is kept by an occasional reference to the compass which is held in front of you or placed upon the ground.

Maps of various scales should be issued to members of the class, who should determine the distance in terms of yards, miles, or paces, and the magnetic azimuth between designated points in accordance with instructions given in this lesson.

QUESTIONS FOR REVIEW

1. What is meant by the expression, "orienting the map?"
2. What is meant by the true and magnetic meridians?
3. What is meant by the declination of the needle?
4. What is the agonic line?
5. What are isogonic lines?
6. What is the declination of the needle to the east of the agonic line? To the west?
7. Describe three methods of determining approximately the true meridian.
8. Describe two methods of orienting the map.
9. Describe two methods of locating your position on the map.
10. Describe the methods of scaling distances on the map.
11. What is meant by the magnetic azimuth of a line? The true azimuth of a line?
12. What is a protractor?
13. Describe the use of the protractor in determining the true and magnetic azimuth of lines.
14. Practical problems in determining distance and azimuth of points on the map should be given the class.

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LESSON VI

CONVENTIONAL SIGNS

Having learned how to read distances and directions on the map, we will now consider the many natural and artificial ground features of importance and the method of representing them on the map.

In order that all may be able to read the map when completed, we must have some fixed method of representing these ground features. With this in view the United States Geographic Board adopted, in 1912, a system of conventional signs for the use of all map-making departments of the government. At the close of the lesson are those that pertain to the work to be covered by this book. Members of the class should be required to reproduce these signs as neatly as possible, and this lesson should be devoted to that purpose.

The instructor should superintend and criticise the work; especially should he avoid the usual tendency of making the signs too large. The ability to neatly reproduce these conventional signs should be included in the examination over this subject. When you find some idle moments with a pencil and paper at hand, your time may be profitably employed by practicing the construction of conventional signs.

Just a few words about pencils would not be amiss at this particular point.

The best for plotting are the hard kinds corresponding to Faber's Siberian HHHH and HHHHHH, especially for drawing fine lines and making points. For most kinds of work, a sharp-pointed pencil is used. For drawing long, straight lines, a chisel-pointed pencil should be used to produce a line of uniform breadth. For sketching and filling in conventional signs, softer pencils are preferable, such as correspond to Faber's HB. To keep the point always in good condition one should have a piece of fine sandpaper at hand for that purpose,

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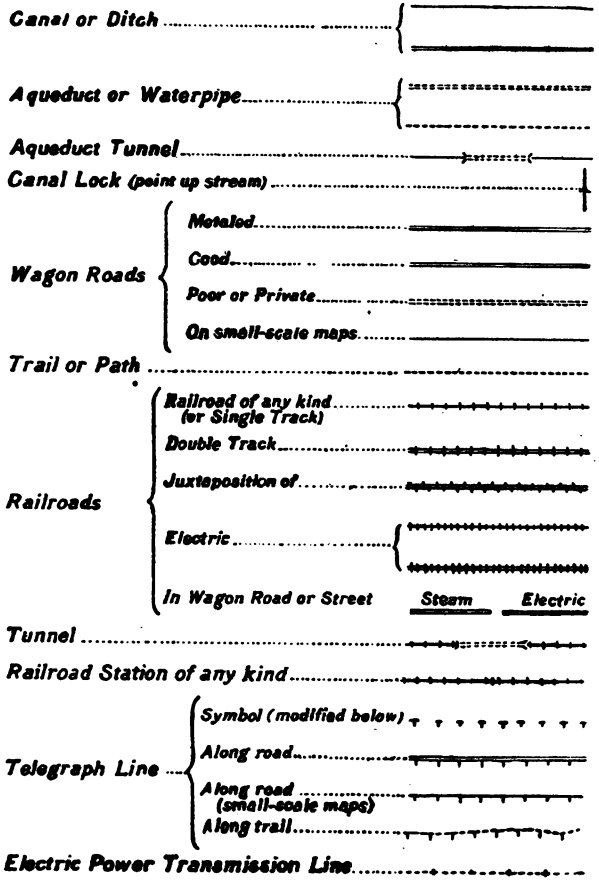

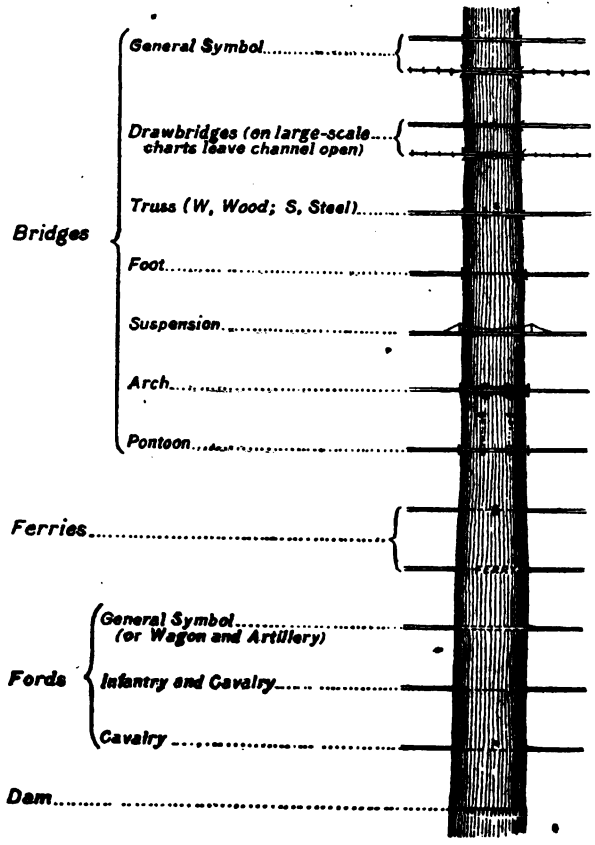

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Good Landing Place for Aeroplanes

Possible Landing Place for Aeroplanes

Buildings in general

Ruins

Church ... ± or ✝

Hospital ... HOS

Schoolhouse ... ± or SH

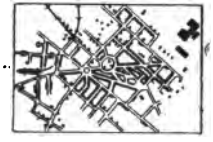
Post Office ... PO

Telegraph Office ... ± or TO

Waterworks ... WW

Windmill ... ⊼ or ⊼

City, Town, or Village



City, Town, or Village (generalized)

City, Town, or Village (small-scale maps)
- Capital ... ★
- County Seat ... ●
- Other Towns ... ○

Fences
- Fence of any kind (or board fence)
- Stone
- Worm
- Wire — Barbed — Smooth
- Hedge

Streams in general

Intermittent Streams

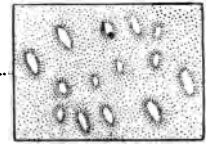
Lake or Pond in general (with or without tint, waterlining, etc.)

Salt Pond (broken shoreline if intermittent)

Intermittent Lake or Pond

Spring

Sand Dunes



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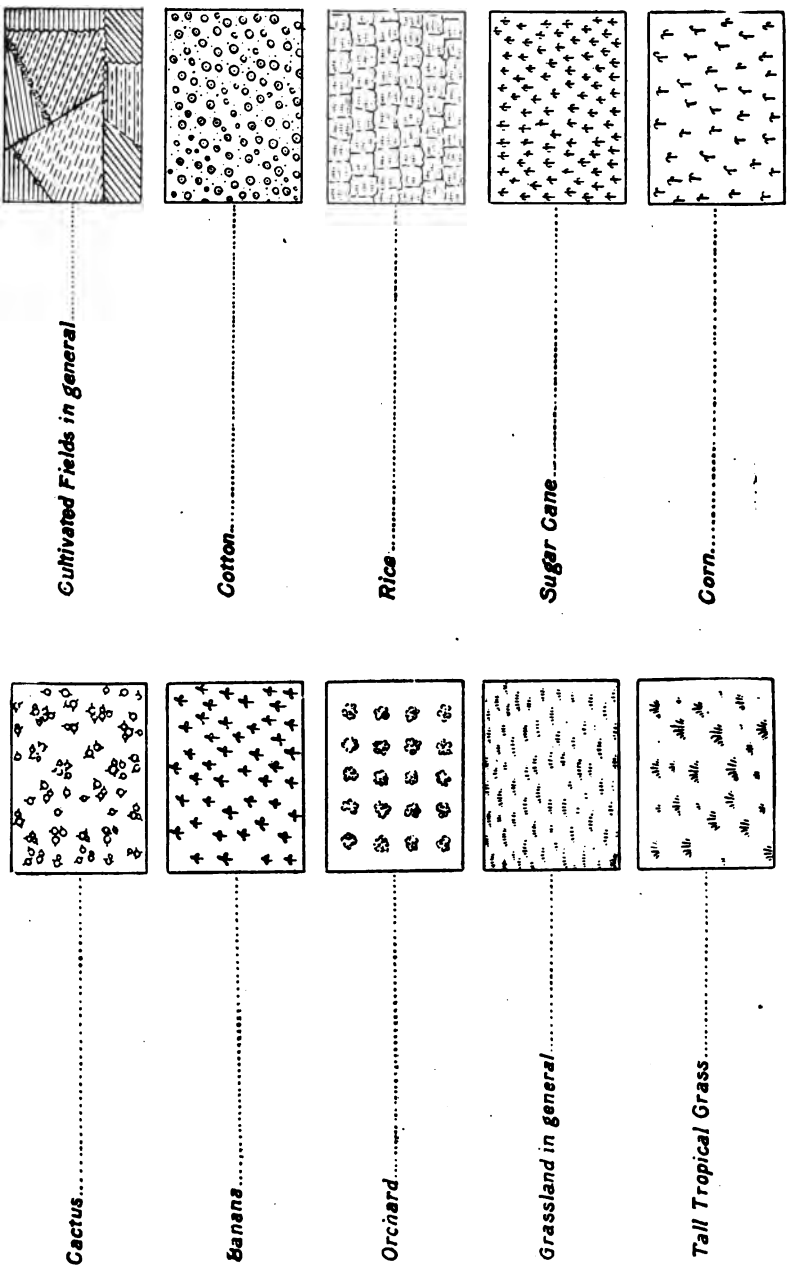

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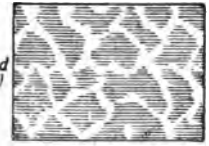
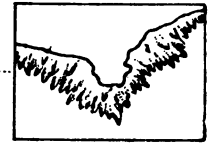
Shorelines — Surveyed
Unsurveyed

Shores and Low-Water Lines

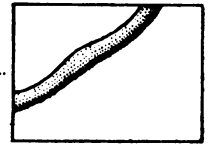
Tidal Flats of any kind (or as shown below)



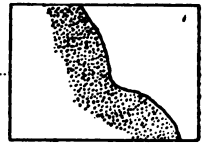
Rocky Ledges



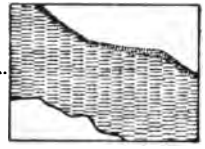
Sand



Gravel and Rocks



Mud



Regimental Headquarters

Brigade Headquarters

Division Headquarters

Corps Headquarters

Infantry in line

Infantry in column

Cavalry in line

Cavalry in column

Mounted Infantry

Artillery

Sentry

Vidette

Picket, Cavalry and Infantry

Support, Cavalry and Infantry

Wagon Train

Adjutant General

Quartermaster

Commissary

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Medical Corps

Ordnance

Signal Corps

Engineer Corps

Gun Battery

Mortar Battery

Fort
Redoubt
} *True plan to be shown if known*

Camp

Battle

Trench

When color is used execute the following in red

Abattis

Wire Entanglement

Palisades

Contact mines

Controlled mines

Demolitions

AUTHORIZED ABBREVIATIONS

A.	Arroyo
abut.	Abutment
A.	Arch
b.	Brick
B. S.	Blacksmith Shop
bot.	Bottom
Br.	Branch
br.	Bridge
C.	Cape
cem.	Cemetery
con.	Concrete
cov.	Covered
Cr.	Creek
cul.	Culvert
D. S.	Drug Store
E.	East
Est.	Estuary
f.	Fordable
Ft.	Fort.
G. S.	General Store
gir.	Girder
G. M.	Grist Mill
i.	Iron
I.	Island
Jc.	Junction
k.p.	King-post
L.	Lake
Lat.	Latitude
Ldg.	Landing
L.S.S.	Life Saving Station
L.H.	Lighthouse
Long.	Longitude
Mt.	Mountain
Mts.	Mountains
N.	North
n.f.	Not fordable
p.	Pier
pl..	Plank
P.O.	Post Office
Pt.	Point
q.p.	Queen-post
R.	River
R.H.	Roundhouse
R.R.	Railroad
S.	South
s.	Steel
S.H.	School House
S.M.	Saw Mill
Sta.	Station
st.	Stone
str.	Stream
T.G.	Toll Gate
Tres.	Trestle
tr.	Truss
W. T.	Water Tank
W. W.	Waterworks
W.	West
w.	Wood

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being careful to remove any lead dust from the point before using. Much more depends upon the proper sharpening of a pencil, and afterwards keeping it so, than is commonly supposed.

Most drawings to be inked are first constructed in pencil, the lines being made with as little pressure and as fine as is possible to show distinctly.

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LESSON VII

RELIEF MAPS

We have learned how to determine from the map the horizontal distances between points on the ground, the direction of one point from another, and the conventional signs representing the various terrain features, but, in order to have a better knowledge of the earth's surface, we must have some method of rapidly determining elevations. In other words, we must know how high the hills are and how deep the valleys are.

This is done by means of CONTOURS, which are lines cut from the earth's surface by imaginary horizontal planes at equal intervals from each other.

Suppose that the territory represented by map, Fig. 8, were submerged, and later the water begins to subside by a succession of falls of the water level of 20 feet, each time leaving a deposit of silt at the water line. Eventually the whole terrain emerges, and would appear roughly as shown in Fig. 9. The silt deposits of the various water lines would represent actual contours on the terrain itself.

The whole subject of contours may be made absolutely clear by the construction of relief maps. The method which will be described is a decided departure from previous methods. Instead of the sand box, moulder's wax is used. This material lends itself admirably to this class of work, due to the fact that it is very plastic, retains its consistency, and, when the relief is completed, permits of vivid representation of all terrain features by means of indentations in the wax.

In order to be successful in this work the moulder's wax must be used. Do not attempt to use the sand table. The latter answers the purpose very well for indoor work in field fortifications, but it will not do for topographical work. Every organization and military institution should secure enough of the wax for relief

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map construction in connection with map reading and instruction in Minor Tactics.

CONSTRUCTION OF RELIEF MAPS

The first necessity is a table constructed as shown in Fig. 7. The two enclosures on top of the table are 18″ square, interior measurements (the same dimensions as the Gettysburg-Antietam 12″ sheets). The flange enclosing the squares is one-fifth of an inch thick and an inch and a half in width. The top of the table should be perfectly level, and the flange of uniform thickness and planed. Also secure a rolling pin of hard wood,

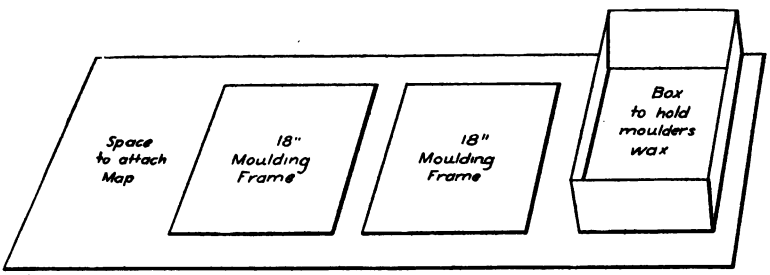

FIG. 7

22″ long and about 4″ in diameter. A sufficient amount of moulder's wax should be secured. This may be purchased from Stewart & Company, 24 Broadway, New York City, and presumedly from other dealers. The wax comes in different colors; the olive-green is preferable for this work. The price of the wax in small orders is about twenty cents per pound, and, when ordered in large quantities, it may be secured at a reduced rate. It takes about twenty pounds to construct one of the Gettysburg-Antietam 12″ sheets, but is well worth the investment.

As, without doubt, you will have need to use the Gettysburg-Antietam 12″ sheets in connection with studies of minor tactics, such as "Studies in Minor Tactics, 1915," and "Small Problems," etc., let us construct a relief map of one of those sheets. The necessary 12″ sheets, unmounted, included in the texts

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referred to above may be secured from the Book Department, Army Service Schools, Fort Leavenworth, at a surprisingly cheap price.

The table, moulder's wax, and maps having been secured, the actual method of construction is as follows:

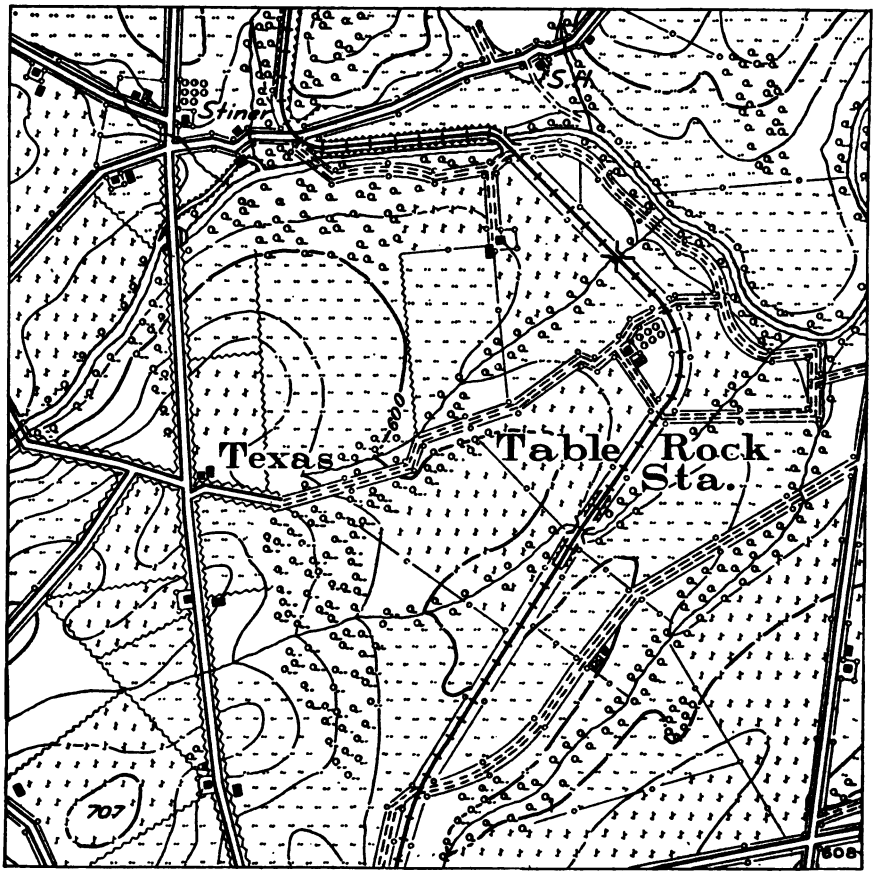

FIG. 8

Place a sufficient amount of wax in each of the squares, and roll off flush with the top of the squares, so that you now have two sheets of wax each one-fifth of an inch thick. If the wax sticks to the tray and roller, apply a little talcum powder Place the map over one of the

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squares, and, with a blunt stylus, trace over the lowest heavy contour (20 feet) on the map, leaving an impression of same on the wax. Cut out that portion of the wax the surface of which, according to the map,

FIG. 9

would be below the contour just traced. Take the remainder of the sheet of wax and place it upon the base established in the other square. Refill the square from which the wax has just been removed, roll as before,

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and trace the next heavy contour. Continue this operation, which will result in an incomplete relief map similar to that shown in Fig. 9.

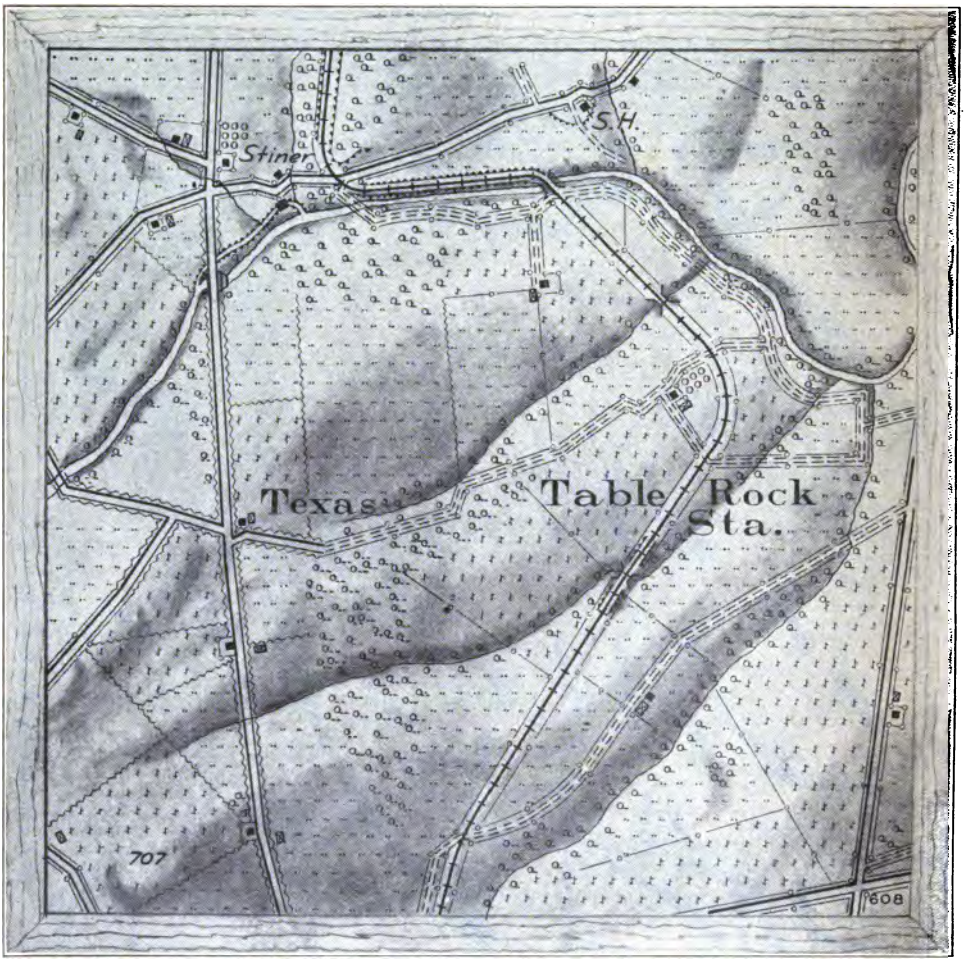

FIG. 10

Next, slope off abrupt surfaces between the heavy contours by moulding in small pieces of wax by hand, and the map is then completed in so far as the relief is concerned.

Next, all of the natural and artificial features of the terrain are represented by indentations in the wax. This is easily done

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by whittling out small, soft pine sticks to represent the various conventional signs, as, for example, a square end stick for buildings, a round end for trees, etc. Roads and railroads may be draw in by means of a stylus and a straight-edge. Letters and figures may be drawn in, or, better, stamped in with rubber stamps or steel type. Every feature is easily represented, and quickly indented on the surface of the wax. When you have no further use for a particular relief map, it may be torn up and another one constructed from the same material. Fig. 10 represents the completed relief map.

With the mechanical means explained above, the student is absolutely sure of constructing the relief map correctly. Having done this work, it follows automatically that he is able to read a military map.

The following principles of contouring may be noted in connection with Fig. 9:

1. That all points on a contour line have the same elevation above the datum plane.

2. That, where the contours are equally spaced, the slope is uniform.

3. That, where contours are straight and evenly spaced, the ground is a sloping plane.

4. That the contours of a vertical surface lie on top of one another as in palisades.

5. That, if the slope in rocky formations is over the base, then only can contours cross.

6. That every contour closes upon itself or extends entirely across the map.

7. That on water-sheds the contours are convexed toward the base of the slopes.

8. That in water courses the contours are convex toward the sources of the stream.

9. That contours far apart indicate gentle slopes.

10. That contours near together indicate steep slopes.

SUGGESTIONS TO INSTRUCTORS

As a knowledge of map reading goes hand in hand with the study of tactics, it is believed that a few words at this

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point regarding the co-ordination of the work would not be amiss.

It has been found by the author that pleasing results with beginners may be obtained by constructing relief maps of the terrain involved in small tactical problems. Attention is invited to Sketch No. 1, page 5, "Studies in Minor Tactics, 1915." Select the 12″ sheets comprised in this section; build up each sheet as above described; join the sheets together and you have the desired area for the first part of the problem. Then, with the war game set, you are ready to proceed with the text. Detail two or three students each day to construct the area for the following day. The relief map work, after the class has been properly instructed, should be conducted by detail outside of the class, and eventually all will have an opportunity to construct a relief map without seriously interfering with their work or recitations. Having all of the paraphernalia necessary for the work at hand, two men should be able to construct a relief map of one of the 12″ sheets in about two hours.

Assuming that Part I of the text referred to will constitute part of the course: it deals with an infantry regiment that detrains, advances, reconnoiters, and attacks an enemy in position, pursues, halts for the night, establishes outposts, prepares and occupies a defensive position, withdraws therefrom and retreats. All of these dispositions are clearly and vividly brought before the mind of the beginner by the aid of the relief map, and gains his interest at the start. Later, when all have become more proficient in map reading and tactical dispositions, the ordinary map may be substituted.

This is considered an important lesson, and, to obtain successful results, much depends upon the demonstrations and explanations of the instructor.

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LESSON VIII

METHODS OF DETERMINING DIFFERENCES OF ELEVATION

From the relief map constructed in the previous lesson, the student should now understand what contour lines are, and the necessity of placing contour lines on maps in order to form a correct idea of the locations and extent of elevations and depressions of the earth's surface.

The surface of the ground is either level or sloping. As one walks along a level course, his elevation naturally remains the same, while, if he walks along a sloping course, his elevation increases or decreases according as he is going up or down hill.

It has been found that the up-hill end of a line 57.3 feet long which has a slope of one degree is one foot higher than the down-hill end. Computing from these figures, we are able to determine the difference of elevation between any two points if we know the distance and the angle of slope between them. The angle of slope may be determined by various instruments especially prepared for that purpose. A very practicable method of ascertaining angles of slope is by means of the slope-board, which is inexpensive, easy of construction, and never gets out of adjustment.

Construction of Slope-Board

On your drawing board (see Fig. 11), construct *DC* perpendicular to *AB*, then when a point is sighted along the straight-edge *AB*, the plumb line attached at *D* makes the same angle with the perpendicular *DC* that *AB* makes with the horizontal. This, of course, assumes that your drawing board is perfectly square.

Lay off *DE* 5.73 inches long on *DC*, then, with the radius *DE* describe the semicircle *FEG*. Lay off from *E* toward *F* and *G* successive distances of one-tenth inch along the arc. These divisions represent degrees, because one degree in a circle of 5.73 inches radius gives a chord of one-tenth inch.

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Extend these degree marks to the foot of the board with a ruler as shown in Fig. 11.

To read slopes, attach a plumb line at *D*, sight along *AB* at the object, keeping the board in a vertical plane. When the plumb line comes to rest, press the string against the edge of the board with the fingers and read the angle marked.

OTHER LEVELING INSTRUMENTS

There are several varieties of clinometers (hand instruments for reading angles of elevation). These instruments, although more convenient than the slope-board, are rather expensive to issue to a large class, or for individuals to purchase. If purchased, full directions accompany them.

SCALES OF MAP DISTANCES AND THEIR USE

Before taking up the subject of scales of map distances, a few terms which will be used frequently in the future will bear explanation at this point.

V. I. means the vertical interval between contours.

H. E. (Horizontal Equivalent) means the horizontal distance on the ground between two contours.

M. D. (Map Distance) means the horizontal distance between two contours on the map.

A Normal System of scales has been prescribed for the U. S. Army field sketches as follows:

Sketches of large areas	1 inch	= 1 mile, V. I.,	60 feet.
Road sketches	3 inches	= 1 mile, V. I.,	20 feet.
Position sketches	6 inches	= 1 mile, V. I.,	10 feet.
Fortification sketches	12 inches	= 1 mile, V. I.,	5 feet.

It will be seen that as the scale is increased the vertical interval between contours is proportionally decreased, so that by this system the M. D. is always the same for the same angle of slope whatever the scale of the map may be.

The M. D. for any angle of slope may be computed from the following equation:

$$\frac{688 \times \text{R. F.} \times \text{V. I.}}{\text{Angle of slope.}} = \text{M. D.}$$

In which 688 equals the horizontal distance in inches on a one-degree slope necessary to give a rise of one foot.

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The V. I. is expressed in terms of feet. However, its function in the equation is only a relative one without regard to denomination.

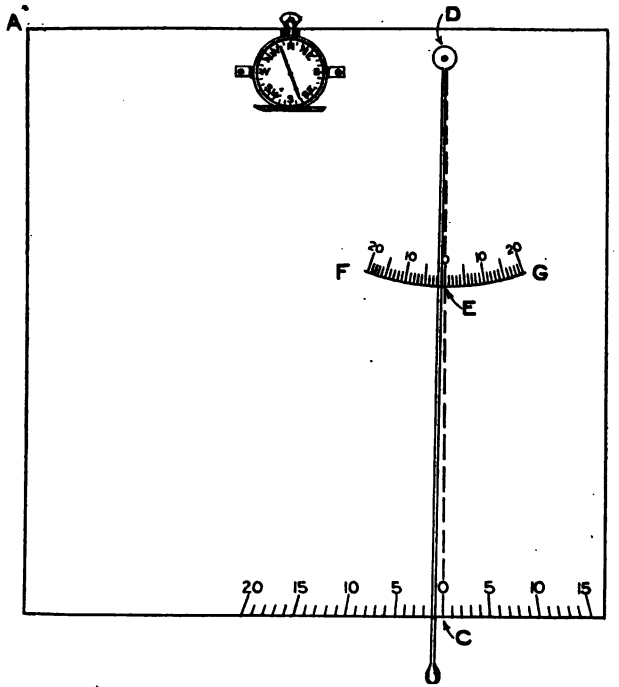

FIG. 11

If the R. F. and V. I. for any sketch made in accordance with the Normal System be substituted in the above equation, the M. D. will be the same for any particular angle.

In view of this let us substitute:

$$\text{R. F.} = \frac{1}{63360}.$$

$$\text{V. I.} = 60.$$

$$\text{Angle of slope} = 1 \text{ degree.}$$

and we have the following:

$$\frac{688 \times \frac{1}{63360} \times 60}{1} = .65 \text{ inch}$$

(the M. D. for one degree slope for any sketch under the Normal System).

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¶ Dividing .65 by $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, 1, 2, 3, 4, etc., we have the M. D. for $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, 1, 2, 3, 4, etc., degrees from which data a scale may be easily constructed. (See Fig. 12.)

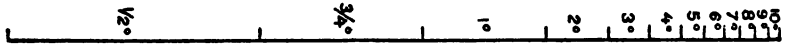

FIG. 12

As we have reading and working scales of distances, the same applies with elevations. Fig. 12 is a reading scale of M. D.'s (Map Distances). By applying this scale to any contoured map under the Normal System, we can readily determine the degree of slope between contours, and, by means of the table below, decide upon the practicability of military operations for the various degrees of slope. Students should be given an opportunity to study contoured maps in connection with the reading scale of M. D.'s and the table given below. The scale shown in Fig. 12 may also be used as a working scale, but a more convenient working scale will be explained later in the lesson.

Degrees of slope.	Operations.
1	Maximum for railroads.
3	Maximum for first-class roads.
5	Practicable for all arms. Somewhat difficult for cavalry to charge descending.
6	Maximum for cavalry to charge in mass ascending. Infantry in close order descends with some difficulty.
7	Cavalry can descend at a trot.
8	Not practicable for heavily loaded vehicles.
9½	Field artillery can no longer maneuver.
14 to 15	Maximum up to which all arms can move.
18½	Light vehicles can ascend.
26	Foot troops can ascend or descend aided by hands.

WORKING SCALE OF ELEVATIONS

We have learned that a horizontal distance of

57.3 feet for 1 degree slope gives a rise of 1 foot.

or

5730 feet = 100 feet rise.

5730 feet = 69760 inches = 100 feet rise.

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Suppose that we are using a scale 3″ = 1 mile, then

1 inch on the map equals 21120 inches on the ground.
68760 ÷ 21120 = 3¼ inches on the map.

Lay off a line 3¼ inches long and divide it into ten equal parts of 10 feet each, and subdivide each of the ten feet divisions into five equal parts of 2 feet each. Place this scale on the same ruler as your working scale of paces or strides, the left of this scale immediately below the left of your working scale of paces or strides. (See Fig. 13.)

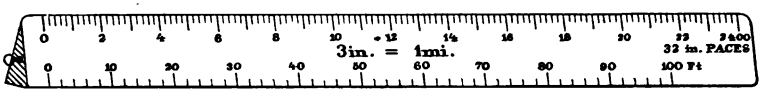

FIG. 13

Now suppose that you have paced a course 500 paces long with a 3-degree slope. Lay off your distance of 500 paces from your working scale of paces (the upper scale), then glance at your working scale of elevations immediately below the 500-point on the upper scale, and you have the elevation for a one-degree slope; multiply this result by three, and you have the difference in elevation between the two points considered. In a similar manner a reading scale of elevations may be constructed under your 6-inch scale of paces or strides. This will cover two faces of your triangular working scale. On the third face should be inscribed a scale of yards for 3 and 6 inches to the mile to be used when the distances are estimated, as may frequently be the case in hasty sketching.

The scale shown in Fig. 13 has been found to be much more practicable at the Army Service Schools as a working scale than the one shown in Fig. 12.

Slopes may be expressed in three ways:

1. *In Degrees:*

A one degree slope indicates that the angle between the horizontal and the given line is 1 degree.

2. *In Percentages:*

A slope is said to be 1, 2, 3, etc., per cent when 100 horizontal units correspond to a rise of 1, 2, 3, etc., of the same vertical units.

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3. *In Gradients:*

Expressed as a fraction in which the numerator represents the difference in elevation, and the denominator the horizontal distance between the two points.

Degrees of slopes are used mostly in military matters, percentages for highway and railway construction purposes, and gradients for trench construction. Approximately, 1 degree slope = 1.7 per cent slope = $\frac{1}{60}$ gradient.

QUESTIONS FOR REVIEW

1. Explain how to construct an attachment to your drawing board for reading angles of slopes.
2. Explain vertical interval, horizontal equivalent, map distance.
3. What is the Normal System of scales for use in the U. S. Army?
4. By making proper substitutions, determine the map distance for ¼, ½, ¾, 1 up to 10 degrees of slope, and construct a scale of M. D's. for same.
5. A contoured map is given to you. From this map determine the various degrees of slope, and decide upon the practicability of these slopes for military operations.
6. Construct a working scale of elevations for 3″ = 1 mile and 6″ = 1 mile, each to read to an elevation of 100 feet. Inscribe these scales on your triangular rule as explained in this lesson. (See Fig. 13.)
7. In what three ways may slopes be expressed? Illustrate.
8. Express a 5-degree slope (*a*) in percentage; (*b*) in gradient.

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LESSON IX

EXERCISES IN CONTOURING

We should now have a very good idea of what contours are and how to determine the elevations of locations by means of our scale of elevations.

Before taking up the subject of sketching, much may be learned about contouring the ground to be sketched by working out the exercises suggested in this lesson. In actual sketching, the contour lines are entirely drawn in by eye, first having given or assumed the elevation of a certain location of the ground to be sketched as a datum plane, and also having outlined the drainage by means of stream lines and elevations of certain controlling points. These controlling points are commonly called CRITICAL POINTS. Critical points, as applied to contours, are points indicating an abrupt change of elevation, as the top of a hill, or an abrupt change in the slope of the hill, also the head and foot of a ravine or water course, the junction of stream lines, etc. Having previously located on your sketch the stream lines and critical points—in other words, thoroughly outlined the drainage of the area—you should proceed to as many of these critical points as will be necessary to obtain a view of the entire area; usually two or three will prove sufficient, and you will find that from these points all of the contour lines may be drawn in by eye with a surprising degree of accuracy.

Figure 14 illustrates the idea. Without even seeing the area, one is able, by means of the stream lines, dry water courses, and elevations given, to draw in the contours about as they would appear if this sketch were actually completed on the ground. In drawing in the contour lines, the student should bear in mind the principles of contouring given in Lesson VII. Each student should draw in the contours on this sketch with a soft pencil and then compare the results. This exercise will impress upon the mind the importance in sketching of first carefully outlining the drainage of the area to be sketched.

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Students should be given tracing paper and contoured maps with instructions to trace upon the paper the stream lines and elevations of critical points, then remove the tracing paper from the map, and interpolate the contours, afterwards comparing the contours interpolated with those of the original map.

One may obtain a great variety of these control sketches from the Book Department, Army Service Schools. Order a complete set of them which will cost but a few cents, and then make mimeograph copies for use of the class.

It will be found that, by the methods suggested above, the student will soon obtain a very accurate idea of what points are really critical in correctly contouring an area, and, when he begins to sketch, these points will stand out vividly on the terrain before him.

PROBLEM

The point *A*, on a 3-inch map, has an elevation of 780 feet. Given the azimuth and a distance from *A*, and the elevation of the following points:

Point	*Azimuth, degrees*	*Distance from A, yards*	*Elevation, feet*
B	20	1,000	920
C	35	500	865
D	50	800	820
E	70	300	820
F	75	1,200	920
G	90	800	840
H	110	500	785
I	115	1,000	890
J	125	700	780
K	150	400	745
L	160	1,100	700
M	180	600	780
N	200	900	845
O	220	400	800
P	245	1,000	895
Q	270	900	860
R	290	400	None given.
S	320	800	880
T	340	300	810
U	355	900	840

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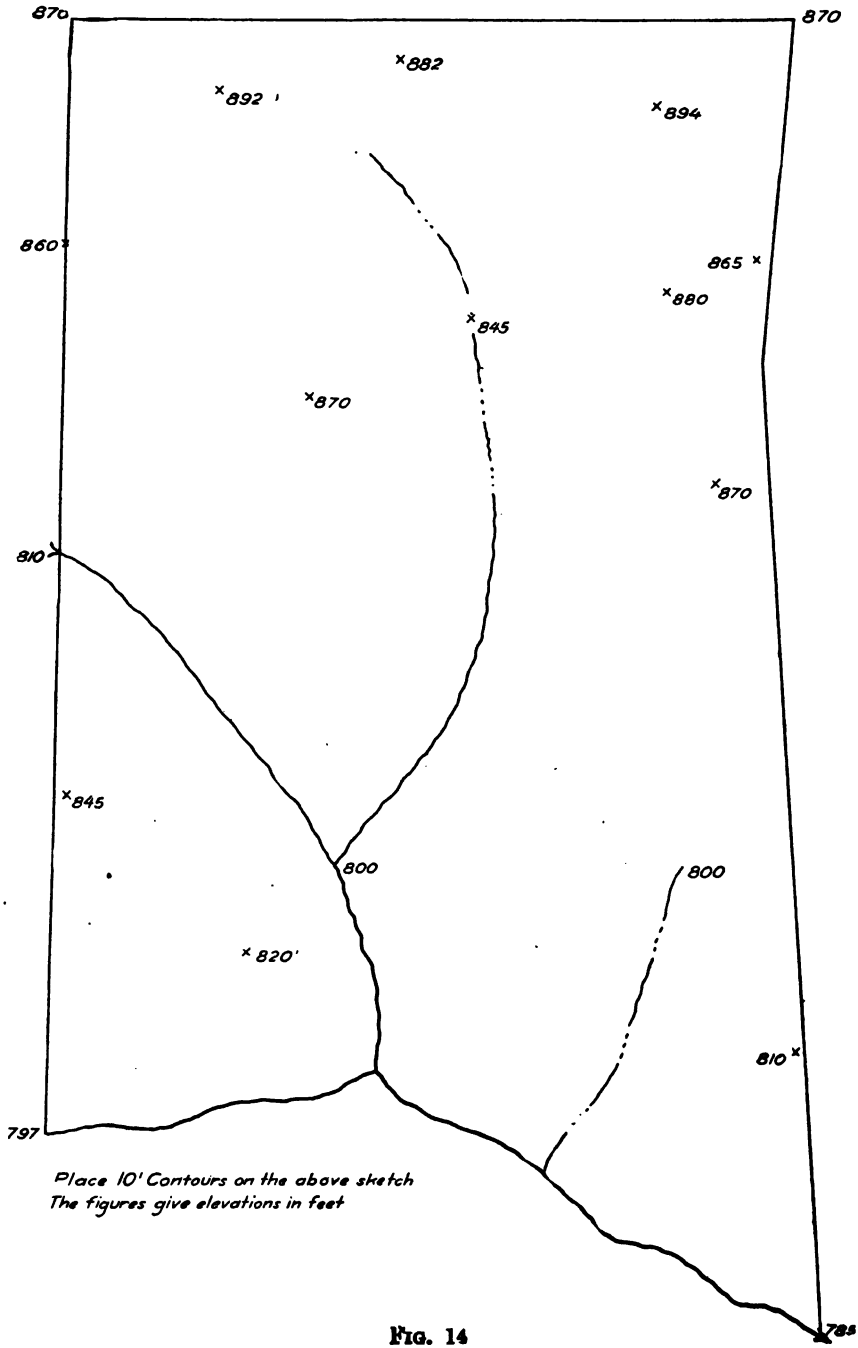

FIG. 14

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A stream flows in the general direction *U-A-K-L*. A branch of this stream flows in the general direction *D-K*, passing midway between *E* and *H*. Another branch in the direction *R-A* flowing for some distance in the same general direction. The latter branch has a uniform slope of one degree.

From the notes given above, plot the stream lines and critical points given and interpolate the contours so as to make a possible representation of the relief under the conditions given. Remember that a 3-inch map under the normal system has a V. I. of 20 feet.

NOTE.—All information necessary in the solution of this problem has been given in this lesson and in the lessons preceding it.

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LESSON X

VISIBILITY

It is often necessary in military operations to determine from the map whether one point is visible from another; whether a certain line of march is concealed from the enemy; how much of a certain area can be seen from a given point; and whether slopes are uniform, concave, or convex. If the map is correct, the above information may be determined very accurately, but it must be remembered that most maps have more or less minor errors in relief so that the visibility of points, lines, and areas cannot be determined to the degree of accuracy that many may assume; also the natural and artificial objects upon the earth's surface interfere in many cases, so when there is a reasonable doubt, and if the opportunity permits, the better method would be to actually verify the visibility by visiting the points concerned.

Visibility by Inspection

By studying the relief map, Fig. 9, the following principles of visibility are obvious:

(*a*) Contours closely spaced on the top of a hill, and gradually getting farther apart toward the bottom, show a concave slope, and all points of the intervening surface are visible from both the top and bottom of the slope.

(*b*) Contours spaced far apart at the top and gradually closer toward the bottom show a convex slope, and neither end of the slope is visible from the other.

(*c*) Contours equally spaced indicate a plane surface, and all intervening points are visible from top to bottom of the slope.

Bearing the above principles in mind, one is often able to tell at a glance whether or not one point may be seen from another.

Visibility by Proportion

The line of sight is determined by drawing a line from the observing point tangent to the point of probable obstruction.

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The visibility of any point, whether determined by proportion or graphically, depends upon the following simple proportion:

Difference in elevation of observing point and point of obstruction.	:	Difference in elevation of observing point and elevation necessary for point in question to be seen.	::	Horizontal distance between observing point and point of obstruction.	:	Horizontal distance between observing point and point in question.

The second term of the above proportion is the unknown quantity, and will be represented by "X."

Example

An observing point has an elevation of 600 feet, the point of probable obstruction an elevation of 400 feet. These points are 800 yards apart. 800 yards in prolongation of this line is a hill 300 feet high. Can this hill be seen from the observing point?

Following out the proportion given above we have:

$$200' : X' :: 800' : 1600'$$

or

$$X = 400 \text{ feet.}$$

$600 - 400 = 200$ feet, the necessary elevation of the point in question in order to be visible from the observing point, consequently the point may be seen.

So it is clear that in many cases the visibility of a point may be determined by a mental calculation of the horizontal distances and the difference in elevation between the observing point, and the point of obstruction. The student should assume points and distances and construct a diagram illustrating the above proportion. By a few exercises of this nature from a contoured map, the student should be able, from inspection, to solve the more simple problems in visibility.

PROFILE METHOD

The more complicated problems in visibility may be readily solved by the profile method. A profile is a line supposed to be cut from the earth's surface by an imaginary vertical plane. To construct the profile, project this line to scale upon a vertical

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plane. (See Fig. 17.) You wish to construct a profile of the line *ABC*. Place the lower edge of a piece of cross-section paper along the line *ABC*. Pick out the lowest contour lines along *ABC*. Naturally they are along the two streams, and both have an elevation of 500 feet. Mark dots on the lower edge of the paper indicating these lowest contours. Guided by the parallel and perpendicular lines of the cross-section paper, dot in the elevations of the remaining contours, allowing one horizontal space for each contour interval. Connect these dots by smooth curved lines, and you have the irregular line shown in Fig. 17. This is the profile of the line *ABC*. Then, by drawing lines of sight from the observing point tangent to the points of obstruction, the visible portions of the line *ABC* are determined.

Visibility problems may be divided into three classes:

1. To determine whether or not one point is visible from another.

2. To determine how much of the ground line connecting the two points is visible from either point.

3. To determine how much of a certain area is visible from a given point.

VISIBILITY OF A POINT

See Fig. 15. Let *A* be the observing point, *B* the point of probable obstruction. To determine whether the point *C* is visible from *A*. (Note that the contour interval is 20′.) As shown in Fig. 16, place the lower edge of the cross-section paper on the line *ABC*. Observing the points, *A*, *B*, and *C*, we find that *A* is the lowest point, *B* is 40 feet higher, and *C* is 115 feet higher than *A*. Let the space between the parallel lines on the cross-section paper represent one contour interval, so *B* will be two spaces higher than *A*, and *C* will be 5¾ spaces higher than *A*. As *A* is the lowest of the three points, its profile position will be at the lower edge of the cross-section paper, or is identical with its map position. The profile position of *B* is *b*, two spaces directly over *B*; the profile location of *C* is *c*, 5¾ spaces directly over *C*. Draw the line of sight from *a* tangent to *b*. It is found to pass beneath *c*, consequently *C* is visible from *A*. The visibility of any

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point may be determined in a similar manner. If there are several points of probable obstruction, locate the profile positions of each point, and, from the point of observation, draw tangents to each profile location and, if these lines fall below the profile location of the point in question, that point is visible.

VISIBILITY OF A LINE

Construct the profile of the line as previously explained. From *a*, Fig. 17, draw lines tangent to the points of obstruction, *x* and *b*. (These are the lines of sight.) From the extremities of the visible portions of the profile, drop perpendiculars to the line *ABC*, and we find, of the line *ABC*, that *AX*, *YB*, and *ZC* are visible portions.

VISIBILITY OF AREAS

From the point of observation, draw several radiating lines through the critical points of the area in question. Find the visible portions of these lines by method suggested above, and connect their extremities, and you have approximately the visible area. (See Fig. 18.)

If the student is provided with a well-contoured map, some cross-section paper, and a pencil, he should be able in an hour's time, by the careful study of this lesson, to master the subject of visibility.

REVIEW

Each student should be given a contoured map, and required to solve the following problems:

1. To determine the visibility of a point by observation.
2. To determine the visibility of a point by proportion.
3. To determine the visibility of a point by the profile method.
4. To determine the visible portion of a straight line by the profile method, the point of observation being in the same straight line.
5. To determine the visible portion of an irregular line, such as a crooked road, the point of observation being outside the irregular line.
6. To determine the visible portion of a given area.

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Scale 3" = 1 mile
V.I. 20'

FIG. 15

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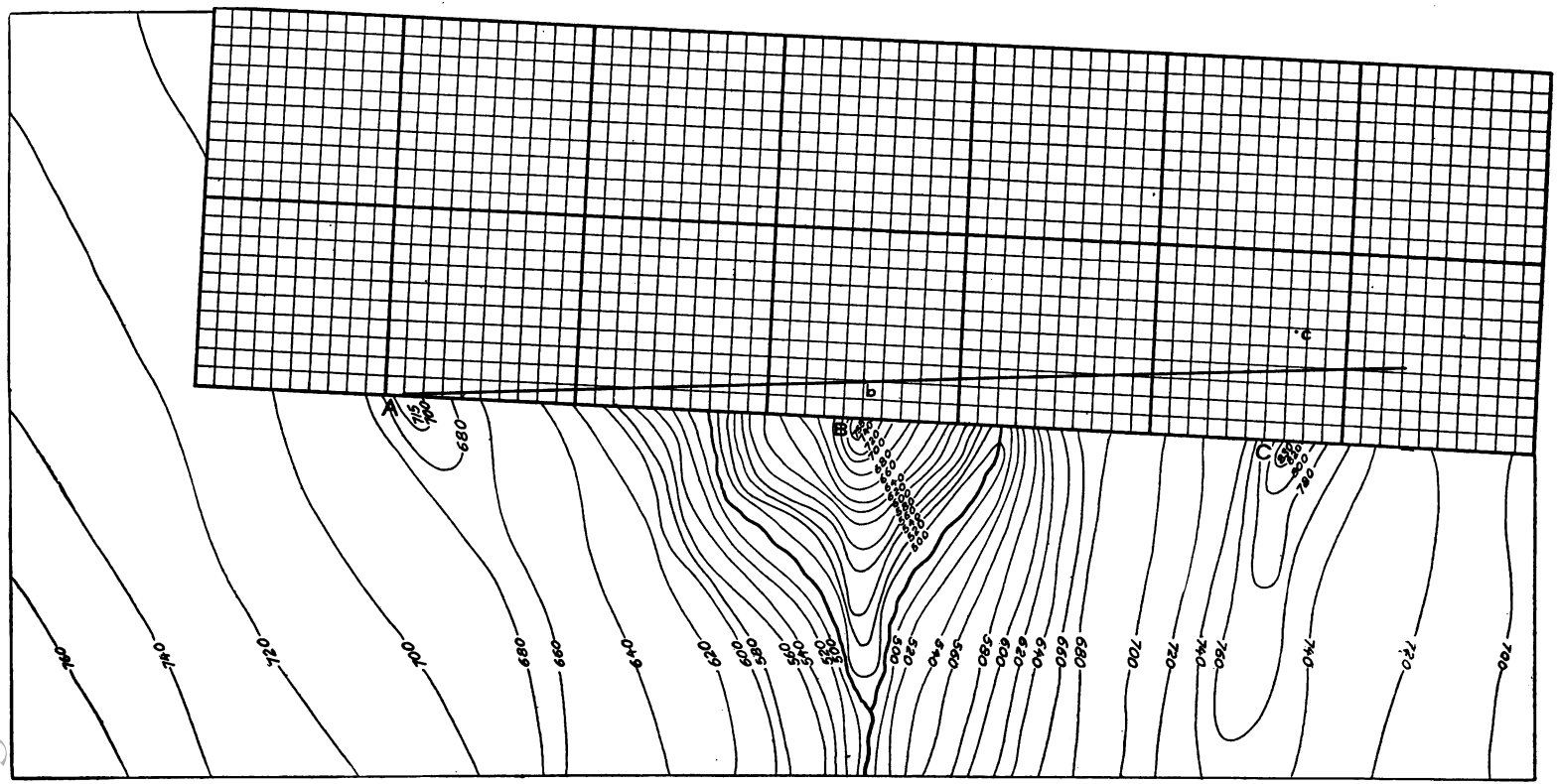

Scale 3" = 1 mile

V.I. 20'

FIG. 16

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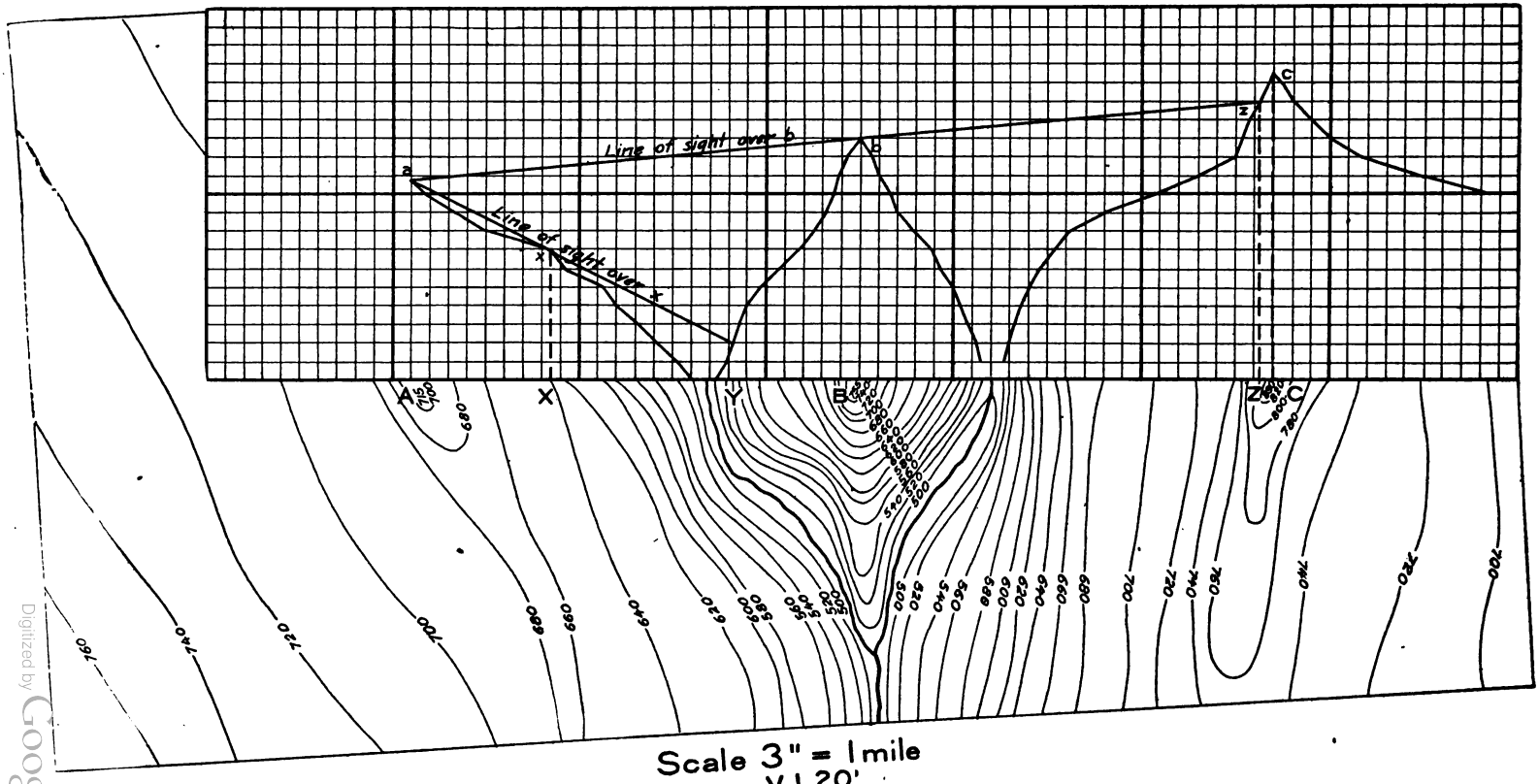

FIG. 17

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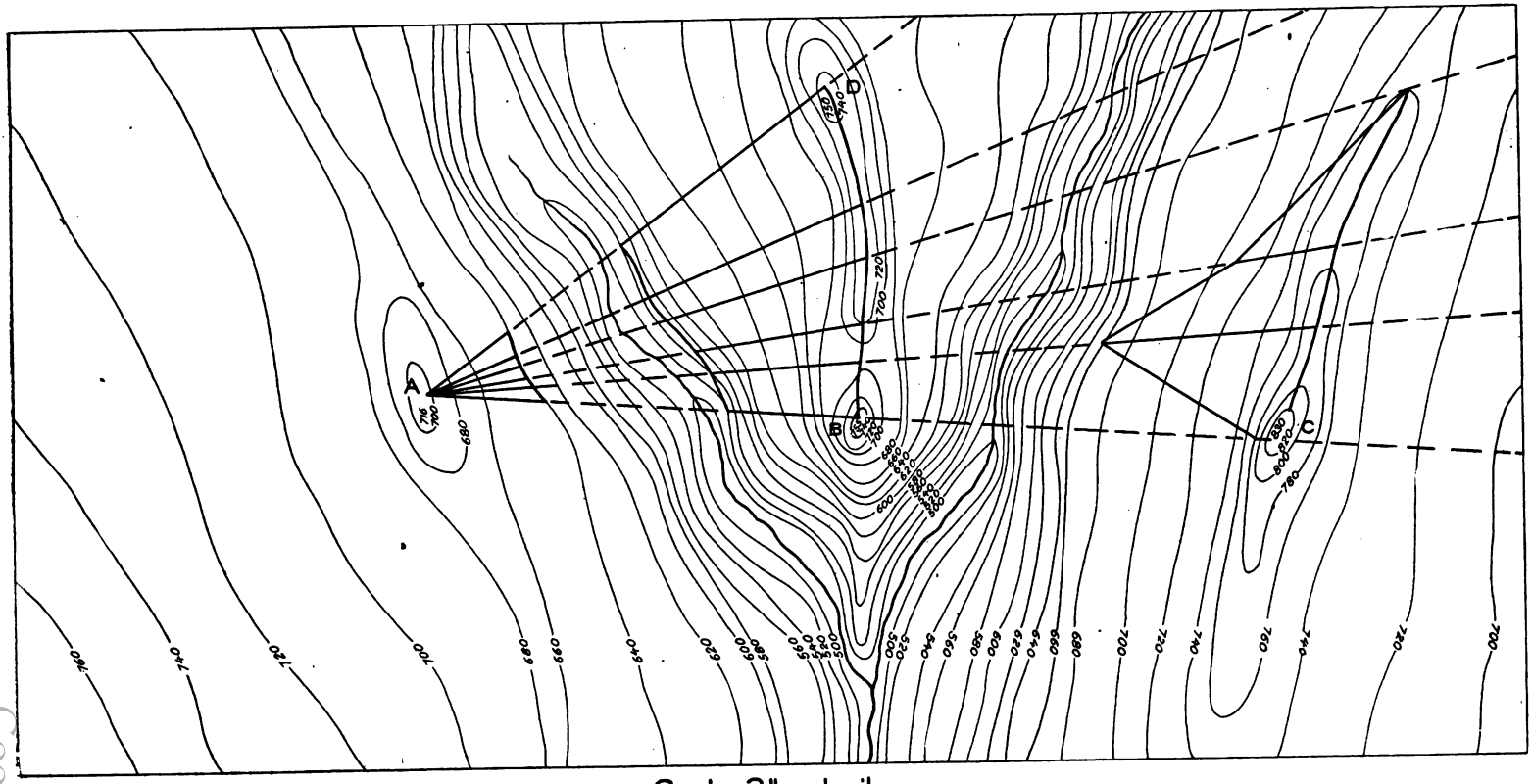

Scale 3" = 1 mile

V. I. 20'

FIG. 18

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PART II

MILITARY SKETCHING

Attention is invited to the B-H Relief Map designed by Capt. A. W. Bjornstad. Most of the leading educational institutions which include military instruction have installed these sets. They are also extensively used in organizations throughout the Regular Army and National Guard. Figs. 25, 26, 27, and 28, illustrating the Road Sketch, Position Sketch, Outpost Sketch, and Place Sketch, are taken directly from the B-H Relief Map. By the use of this relief map the student is able to pursue a course of indoor instruction in map reading, and a course in topographical sketching which is every bit as realistic and instructive as actually sketching the terrain. The relief map is of inestimable value when one considers the factors of time, suitable terrain, and climatic conditions, to say nothing of the great advantage it affords in pursuing a course in tactics, fortification, etc.

In following the course of instruction in sketching outlined in this text in connection with the B-H Relief Map and its special equipment, the student is afforded the same opportunities for the actual work of sketching that present themselves outdoors on actual terrain.

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LESSON XI

FLAT SKETCH

Having completed the course outlined for map reading, we will now take up the subject of military sketching. In a way these two subjects go hand in hand, as one is taught the other is learned. If one thoroughly understands military sketching, he naturally will be able to read a military map, but, for convenience of instruction, the subjects have been divided.

Before taking up the subject of sketching each student should be equipped with a drawing board with an attachment for reading angles of slope, compass, a working scale as shown in Fig. 13, Faber's HB pencil or one of about the same degree of hardness, an eraser, and a pocket knife or pencil sharpener. A tripod in connection with the drawing board is of assistance to the beginner, although not absolutely necessary.

The Engineer drawing board with attached compass and tripod, although excellent, is very expensive, and would not be found practicable on that account with large classes such as would be the case at educational institutions. The improvised drawing board and tripod shown in Fig. 21 are suggested. They are easy of construction and will be found entirely practicable.

Drawing Board

Soft pine board, 13″ by 14″ by 1″. This will allow a surface of 4 square miles for a position sketch, and still enough extra space to secure the paper to the board. The compass may be set into the middle of one side of the drawing board by cutting or boring into the board. The author will not attempt to recommend any particular compass. What is known as the watch compass is issued to organizations of the regular army at present. Some good round case compass that could be set into a round hole in the board is recommended. In anticipating this course, the instructor should write to some dealer for samples, and select the most practicable compass as to cost and efficiency, and then endeavor to secure a discount by ordering for the entire class.

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THE TRIPOD

Select a piece of "Two by four" 5 inches long (see Fig. 21b), and three sticks 4′ by 1″ by ½″, the latter of some tough material which will not be easily broken. About ¾″ from the end of these sticks bore holes ½″ in diameter. At the mid-

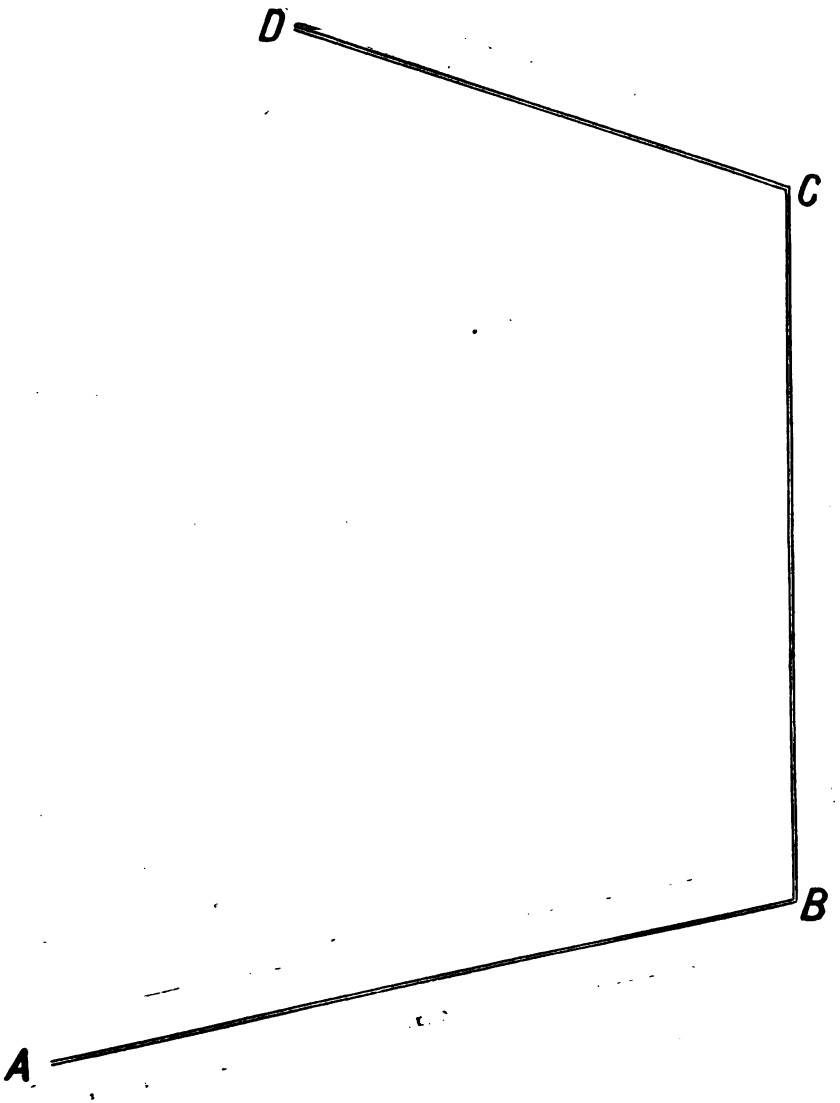

FIG. 19

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dle of one end of the block saw out a slit ¾" wide and extending an inch and a half into the block. By means of wire nails driven as shown in Fig. 21c, attach the three legs to the block,

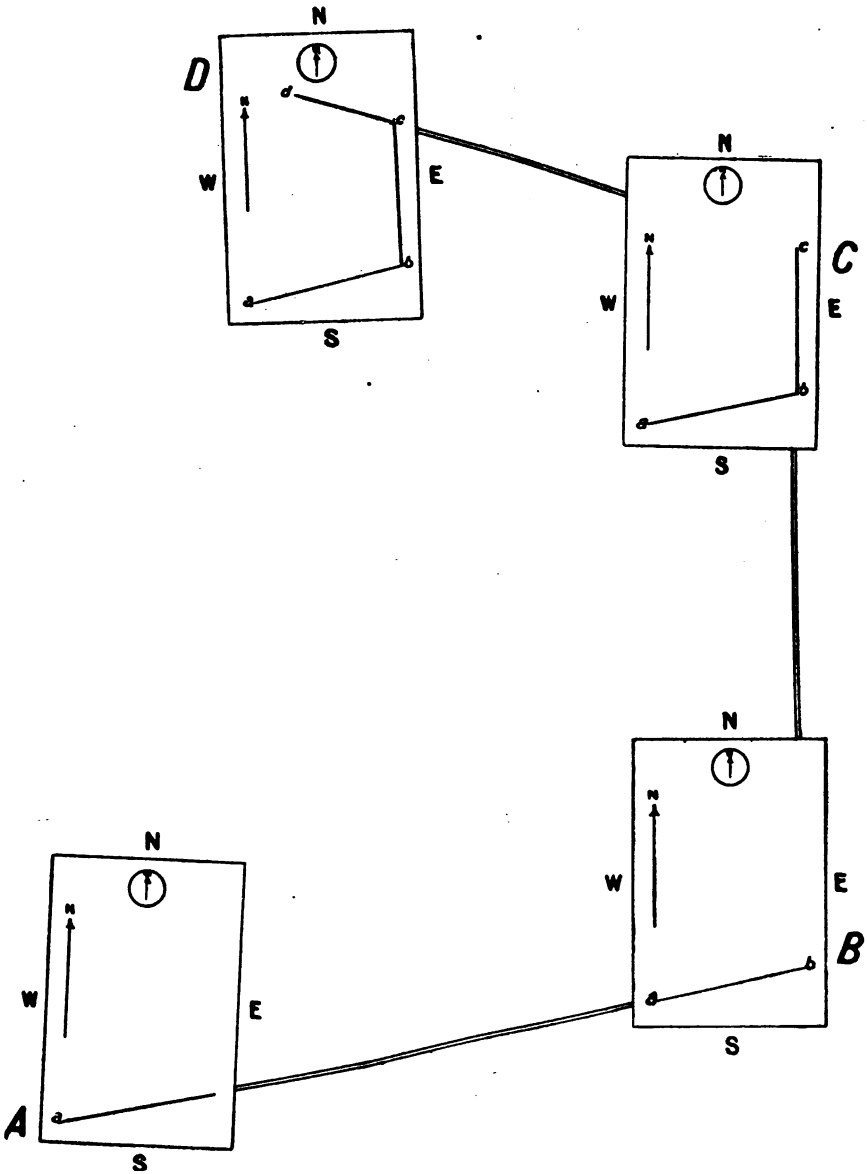

FIG. 20

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one leg in the slit and the remaining two legs at the other end of the block. Then drive a wire nail into the center of the bottom of the block; the nail being of sufficient length so that it will protrude ¾″ out of the block. (See Fig. 21c.) When all of this has been completed, you will have a tripod something like Fig. 21d. Now bore a hole ¾″ deep into the center of the bottom of your drawing board, the diameter of this hole being just sufficient to accommodate the wire nail protruding from the top of the tripod. Now attach the drawing board to the tripod by means of the nail and hole just described, and you will have a drawing board and tripod complete, by means of which the drawing board may be quickly oriented and leveled; also the board may be easily detached from the tripod when it becomes necessary to read angles of slope from the attachment on the board. As stated heretofore, the tripod is of assistance to the beginner, although not really necessary, but is usually discarded by the experienced sketcher as being too much bother in hasty military sketching.

The student, being equipped as noted above, is now ready to begin sketching.

Fig. 19 represents the road *ABCD* to be sketched. On your paper draw a straight line representing the magnetic north. Mark one end of this line N.

In sketching, always hold your drawing board in such a position that the north end of the compass needle and the arrow end of the magnetic north indicated on the paper are pointing in the same direction. In the future we will refer to this operation as "Orienting the board."

Go to the point *A* on the road. (See Fig. 20.) Orient the board. From any convenient point *a* on the board, draw a straight line in the direction *Ab*. Next, pace the distance from *A* to *B*, and, with your scale of paces, 3″ = 1 mile, lay off the line, *ab*, representing the distance *AB*. In locating the initial point *a*, one usually knows the general direction of the course to be sketched, and should select a point of beginning which will afford the greatest use of the paper. For example, if your course takes in an easterly direction, your point of beginning should be near the west margin of the paper.

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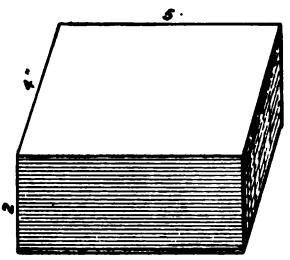

Fig. b

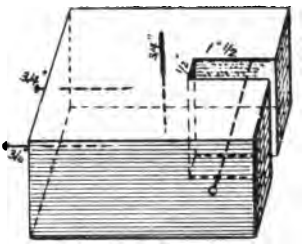

Fig. c.

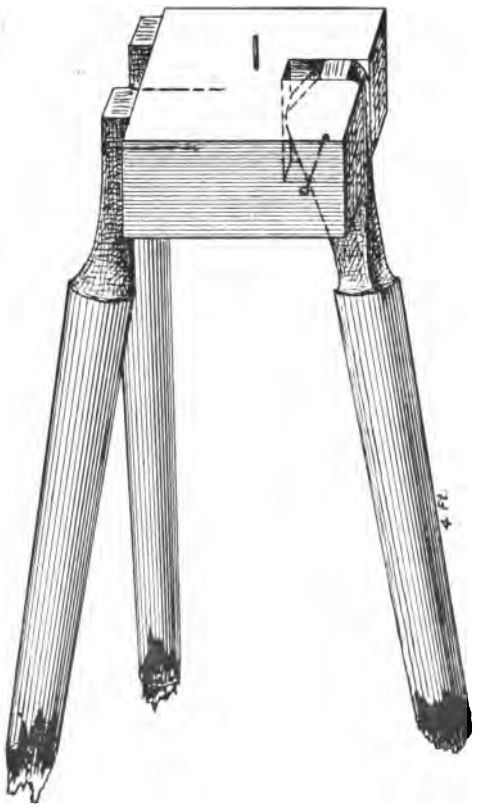

Fig. d

FIG. 21

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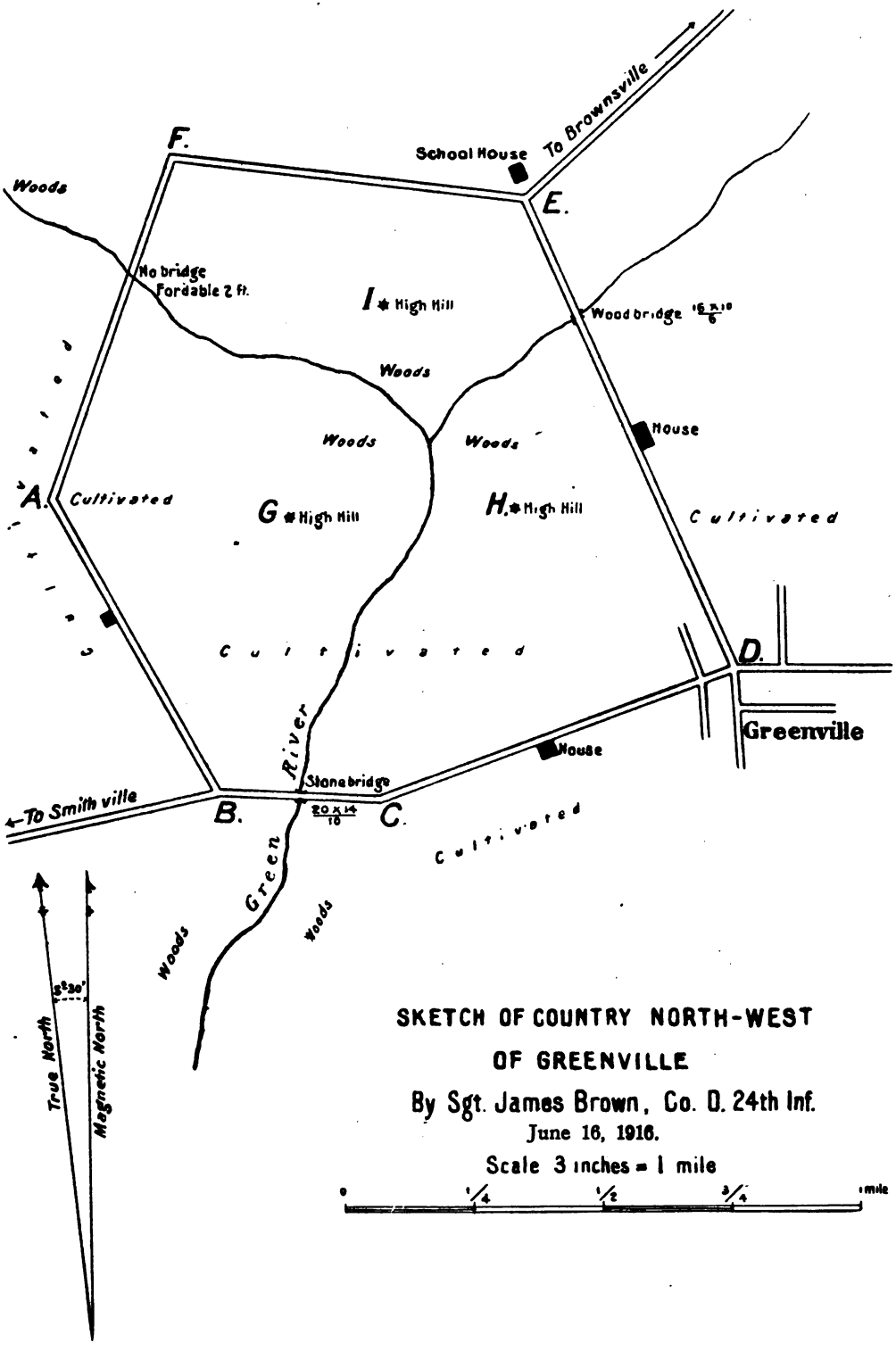

FIG. 22

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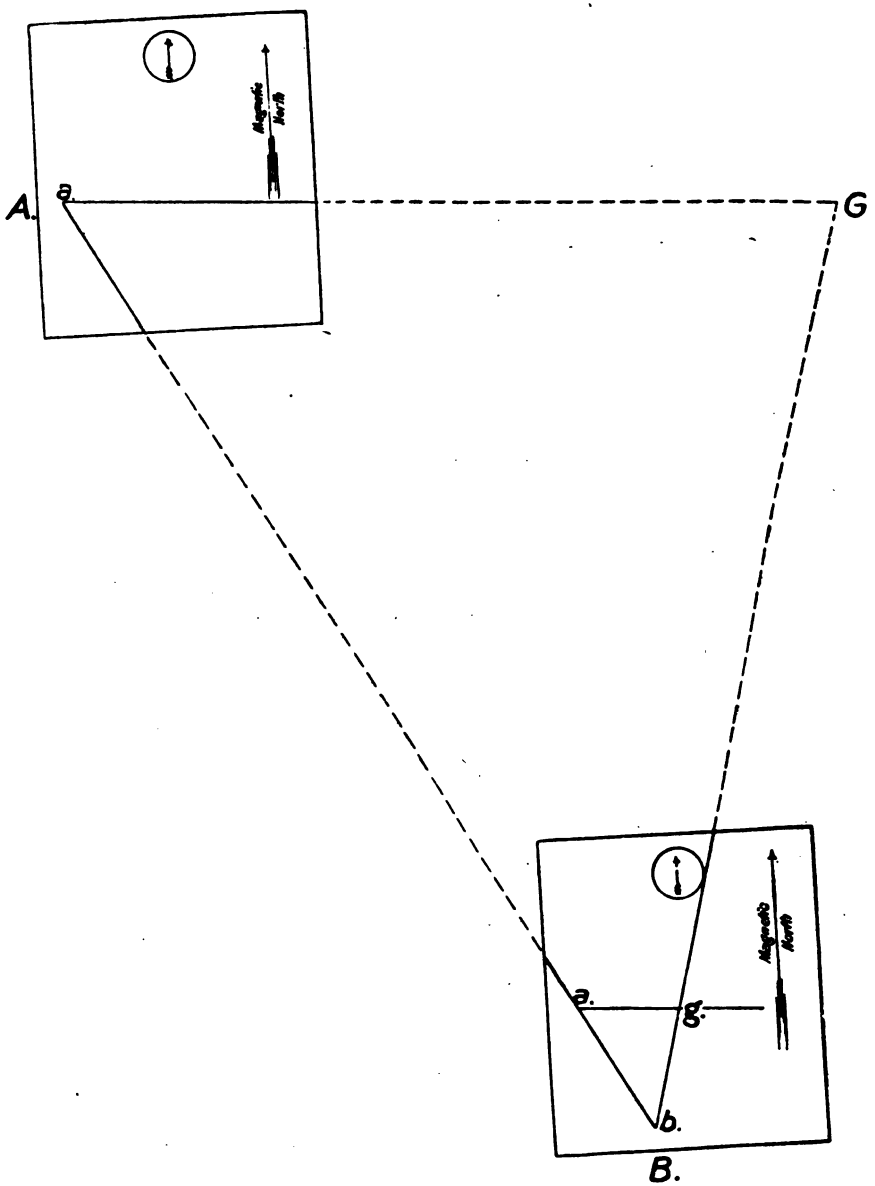

FIG. 23

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Now orient the board at *B*, draw a straight line in the direction *BC*, pace *BC*, and lay off the line *bc*.

Orient the board at *C*, draw a line in the direction *CD*, pace *CD*, and lay off the line *CD*.

The instructor should require each student to plot a short course having several changes of direction. The scale 6″ = 1 mile might be used instead of the 3-inch scale, this making more evident all errors in distance and direction. Results should be compared and errors pointed out. An accurate sketch of the route should be exhibited, and each student's sketch compared with it.

The instructor should then select some longer course in which the points of beginning and ending are the same, as, for example, the course *ABCDEFA*—Fig. 22. This will serve as an excellent check on the work. The methods employed will be the same as described above except that important points to the right and left of the course should be located by intersection, and locations along the course should be verified by resection.

TO LOCATE A POINT BY INTERSECTION

NOTE.—Contouring will not be attempted in this sketch, which is known as a "Flat Sketch." Vegetation may be indicated in writing, and hill tops indicated by a dot or star. (See Fig. 22.)

To locate a point by intersection—as, for example, the hill-top *G*, Fig. 22—orient the board at *A* (see Fig. 23 in connection with Fig. 22); mark the point *a* on the board to correspond to *A* on the ground. Sight in the direction of *B*, and from *a* draw a straight line in the direction of *B*, then sight at the hill *G*, then draw a straight line in the direction of *G*. (Care must be taken to keep the board constantly oriented. In determining the line of sight from the point of observation on the map to some distant point on the ground, pivot the ruler at the point of observation and sight along the upper edge toward the object.) Pace the distance *AB*, orient the board at *B*, and lay off the map distance, *ab*, corresponding to the ground distance, *AB*, then sight at the hill, *G*, and draw a

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straight line from *b* in the direction of *G*. The lines drawn from *a* toward *G* and from *b* toward *G* intersect at *g*, which is the map location of the hill, *G*. In a similar manner any other points, as *H* and *I*, Fig. 22, may be located by intersection from any two favorable points.

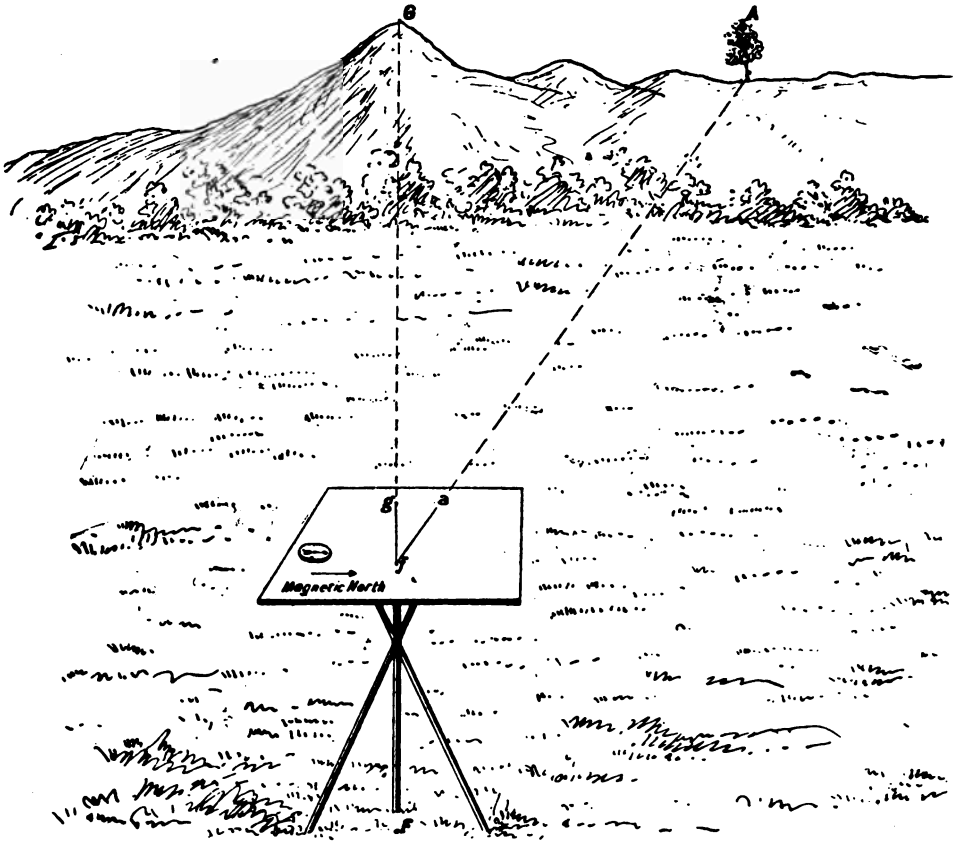

FIG. 24

Angles of less than 30 degrees or greater than 120 degrees at the point of intersection should be avoided, as the two intersecting lines are so nearly parallel that it is difficult to locate the exact point of intersection.

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TO LOCATE A POINT BY RESECTION

Suppose that at the point *F* of the course *ABCDEFA*, Fig. 22, you wish to verify your location. The points *G* and *A* on the ground have already been correctly located on the map at *g* and *a* (see Fig. 24). The sketcher is at the point *F*, which he wishes to locate on the map. He orients the board with the compass, pivots the ruler at *g*, at the same time sighting the hill *G*, and draws a line along the ruler toward his body. Similarly pivot the ruler at *a*, sighting *A*, and drawing a line along the ruler toward his body. This line cuts the *Gg*. The intersection of the lines at *f* is the sketcher's map location.

As the sketcher passes over the course, he should note in writing on his sketch such ground features as bridges, fords, ferries, houses, woods, cultivated fields, villages, high hills, streams, or any other information of importance. (See Fig. 22.) As stated before, the sketch shown in Fig. 22 is known as a "Flat Sketch," no relief being shown.

When completed, the following information should be indicated at some convenient place on the sketch:

1. Location of sketch.
2. Name and organization of sketcher.
3. Date of sketch.
4. Scale of sketch.
5. The magnetic north, and, if the declination of the needle is known at the particular locality, the true north should be indicated also.
6. Reading scale.
7. Contour interval.
8. Scale of map distances.

Nos. 7 and 8 need not be indicated unless the sketch is contoured.

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LESSON XII

ROAD SKETCH

We have learned how to plot on the map ground distances, directions, elevations, and the various natural and artificial ground features of military importance.

We will now make a complete road sketch. The instructor should designate some road; a course of about two miles with several changes of direction is sufficiently long for the beginner. Each student will go over the designated road, plotting distances, directions, elevations, and important ground features.

The sketch should not only include the road itself, but an area extending about 400 yards each side of the road. As a rule, most of this area may be seen from high elevations along the road bed, but occasionally it may become necessary to go to an elevated point outside the road proper to secure all of the details. Objects of military importance, such as high hills, towns, etc., which are more than 400 yards from the road, should be located by intersection. Whenever hills are located by intersection, their elevations should be noted.

The most practicable method of indicating details on sketches made in the field is shown in Fig. 25. Vegetation, especially, should be indicated by words rather than by the proper conventional signs. In short, the best field method is the shortest and most accurate method. In order that the student may become familiar with all of the conventional signs, which is very important when it comes to map reading, the field sketches may be retouched at leisure, employing the proper conventional signs in each case. The beginner should sketch in every detail of military importance in order to train the eye to observe details. Later he may be called upon to submit sketches showing only such information as may be required for particular expeditions.

After the field work has been completed, the instructor should collect the sketches, and note on each sketch all of the glaring defects. Although only one lesson for each of the

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various classes of sketches is given in this text, yet the same old rule of "practice makes perfect" applies.

It must be remembered that there are no hard and fast rules to be observed in sketching. There are a few general principles which must always be applied, but, when it comes to the details of the work, each road or area to be sketched presents new features, and the sketcher must use his judgment as to the shortest and most accurate methods; but, having clearly fixed in his mind the basic principles such as distance, direction, intersection, resection, elevations, and possessing a keen eye for critical points in connection with the drainage of the ground, all of which have been previously explained, he should experience no difficulty in applying the proper principles at the proper time.

A method of sketching the road represented in Fig. 25 will be given in detail. There may be other methods equally good as to the minor details of accomplishing the same results.

You are directed to sketch the road beginning at the bridge near the Langford house, thence about two miles to the north, Fig. 25. It will be noted that this road has frequent changes of direction, which will require more "Set ups" than in the case of a more direct route. It is assumed that the elevation of the floor of the bridge is 90 feet. In case the elevation of the point of beginning is not known, it always may be assumed, and your elevations will be relatively correct throughout the sketch.

Orient the board at 1, and indicate your magnetic meridian as explained heretofore. Sight in the direction of 2 (the first change of direction in the road), and draw a straight line in the direction of 2. Then proceed to 2, and on arriving there you have determined the distance. Note down the location of 2, and, from points 1 and 2, plot in such details as the stream railroad, buildings at the Langford house, etc. Continue the work along the same lines at 3, 4, 5, 6, 7, 8, etc.

Now the subject of contours comes in. If the correct methods are pursued, the contouring will be found to be very simple and interesting. Do not attempt to get the angles of slope to 2, 3, 4, and 5, as the change of elevation is so slight. Remember the principles of contouring brought out in Lesson

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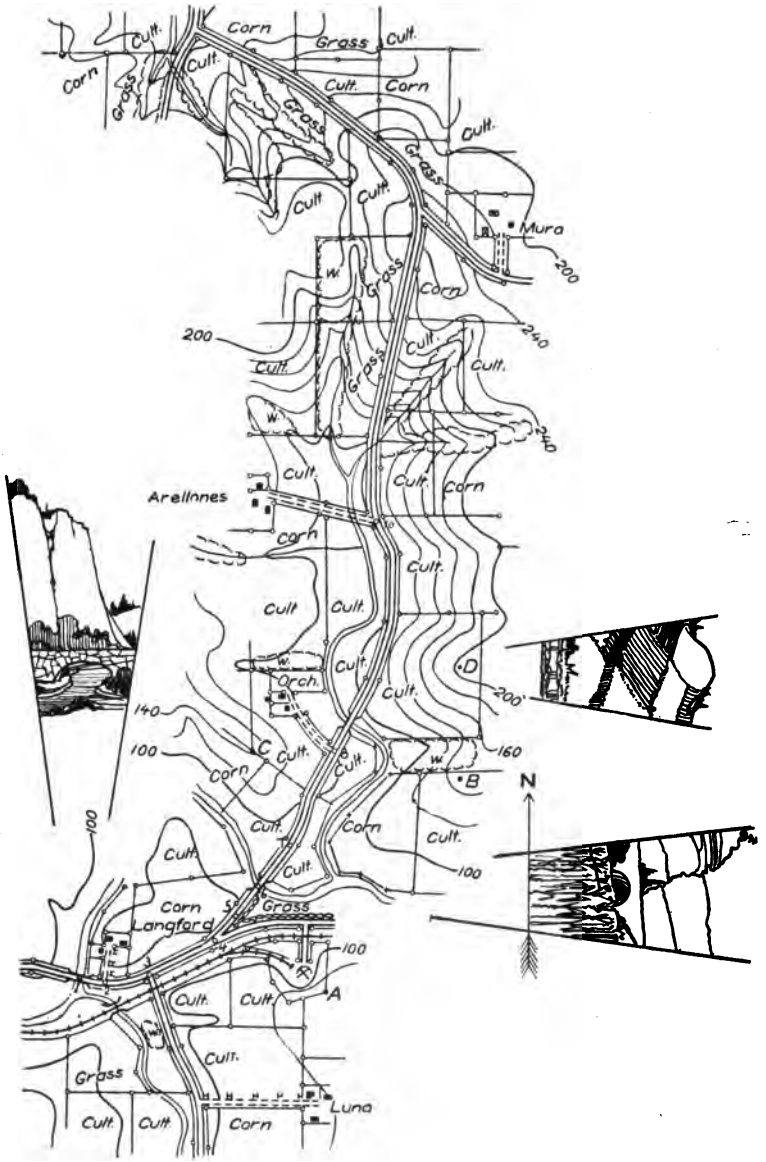

ROAD SKETCH
NEAR LANGFORD BRIDGE
June 16, 1916
By 1st. Lieut. F. B. SMITH, 10th. Inf.
Scale 3" = 1 mile

500 1000 1500 YDS.

M.D.

V.I. 20'

FIG. 45

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LESSON XX

RANGE DATA

The student should now be required to complete sketches on the standard sketch pad in the manner shown in Fig. 46, that is, all important military features should be shown, not only on the sketch itself, but a line should be drawn vertically from the sketch itself till it intersects the three horizontal lines near the top, and on this line should be written in the proper place, the target, the range to that target, and the deflection to that target from a given reference point. In all cases, the reference point will be similarly indicated with a zero deflection. Care should always be taken that the name of the place from which the sketch was made is not omitted from the lower left hand corner and that the single barbed arrow, giving the magnetic north, appears near the circle at the center. The number near the circle should always indicate the relative position of sketches from enemy right to enemy left. The range should, when practicable, be measured with a standard range finder.

Frequently, when the principal thing needed is the military information of the sketch, the sketch itself may be omitted for the purpose of saving time, and direction lines only are then drawn from the small circle towards the targets. At an approximate distance (sometimes, but not always measured to scale), is drawn a quick sketch representing the target only, or sometimes only an X is placed on the line and a word written, such as "ford," "tree," etc., near this mark. An example of this case is given in Fig. 47, which represents what is called the range card, for the same ground given in Fig. 46. It is thus seen that a range card is a simplified landscape sketch which does not require any pictorial ability on the part of the sketcher. The necessary fire data are placed on the upper left-hand corner of the range card in the place provided on the blank. The deflection, however, is given near the top, and is measured in Mils from the reference point. The range is also frequently written along the direction line toward any target. The

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targets are also numbered from enemy right to enemy left, and the firing data for each target are recorded in the space provided. The illustration given in Fig. 47 is that of a machine-gun range card. These cards are made out for each individual gun, and the number in the circle may be supplemented by such additional data as the particular case may require, for example, "No. 1 Gun, Company A, 335 M. G. Bat." The machine-gun range card remains at the position of the gun when the machine-gun crew is relieved. The sketch given in Fig. 48 is another illustration showing how firing data are expressed on a landscape sketch. Though it is desirable that all sketches should be uniform in appearance, the only essential feature that must be adhered to is that the firing data must be expressed directly above the target and near the top of the sketch.

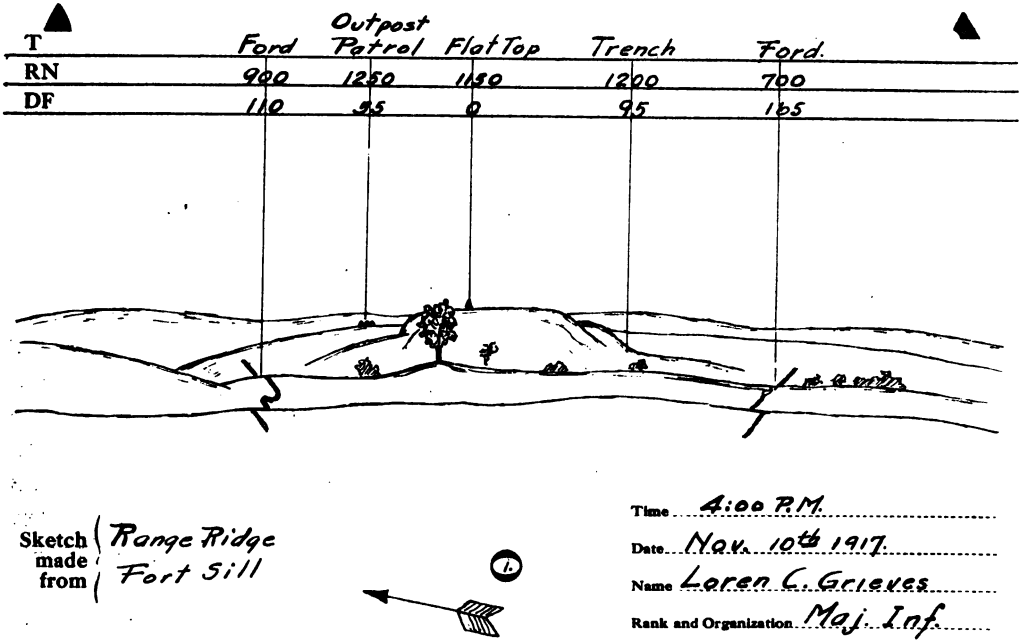

FIG. 46

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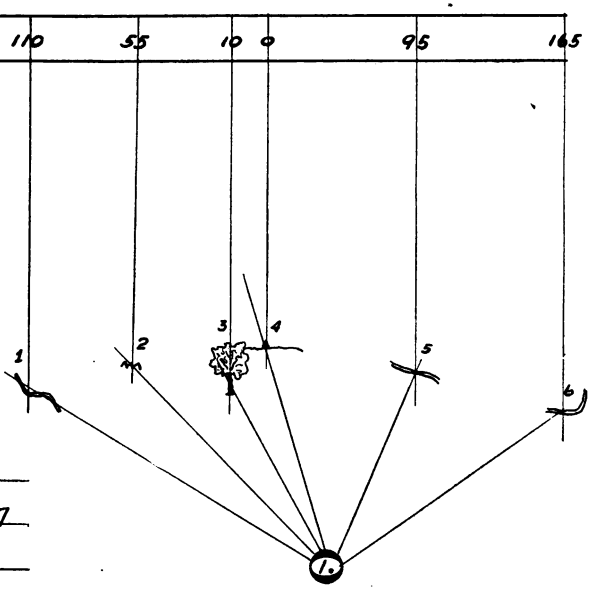
Fig. 49 illustrates a landscape sketch as applied to giving firing data for field artillery. For artillery sketching purposes, the sketch pad blanks should be altered by adding additional horizontal black lines near the top for placing the artillery firing data. There should be at least a one-inch space above the upper horizontal line, used for writing in names of registration points, targets, etc., and for entering their estimated and measured ranges; measured ranges should be underscored. The space covered by the six horizontal lines are used in the order given for entering deflection, deflection difference, site, corrector, and range for the gun position. The deflection difference and corrector of any particular target should be entered only after this data have been determined by actual fire. The deflection (actual deflection from the aiming point)

MACHINE GUN RANGE CARD

TARGET	R N	A S° DEGREES	AS' MILS	C COMPASS BEARING
(1) Ford Bullet Creek	900	-15'	-5	20
(2) Patrol	1250	+15'	+5	40
(3) Lone Tree	750	-15'	-5	56
(4) Flat Top Mark	1150	+20'	+10	64
(5) Trench	1200	0	0	95
(6) Ford	700	-18'	-6	120



Position Range Ridge # 1 Gun

Hour & Date 4:00 P.M. Nov. 10th 1917

Name Loren C. Grieves

Rank & Organ. Major Infantry

FIG. 47

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should already be computed and entered before opening fire, but that data should be changed after delivering fire so as to show the actual data determined by fire. The space below the six horizontal lines and above the body of the sketch is used for noting the angular distances from the reference point to prominent points on targets shown. These angles should be recorded immediately below the lower of the six horizontal lines. Other data pertaining to targets, notes, reference to sub-sketches, etc., may also be placed in this space. The sketch proper is usually confined below the top dim horizontal line, in the same manner as in the sketch previously discussed. The space below the sketch proper should have the same notation as the previous sketches discussed, adding condition of the weather, which is needed in calculating artillery data, and of course such other miscellaneous notations as may be necessary in any particular case.

The student should equip himself the same as in Lesson III.

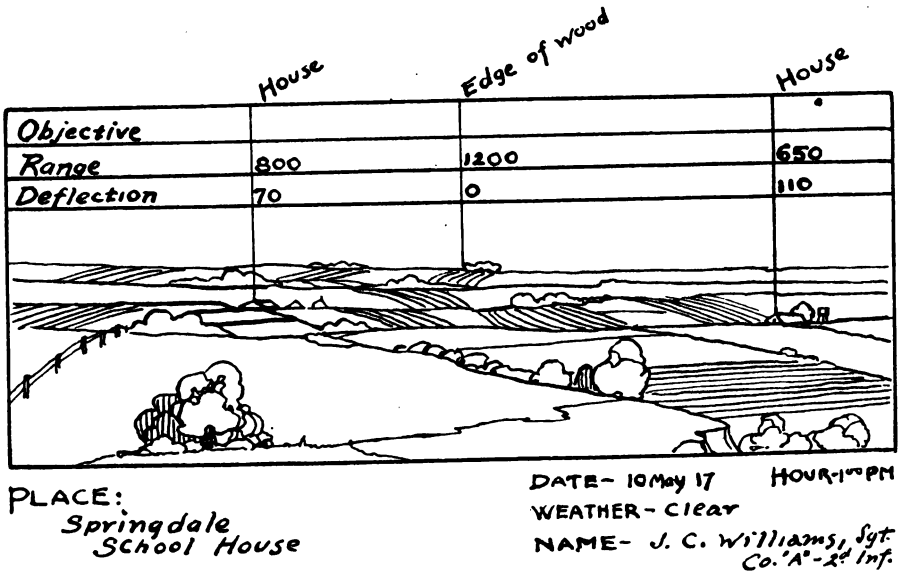

FIG. 48

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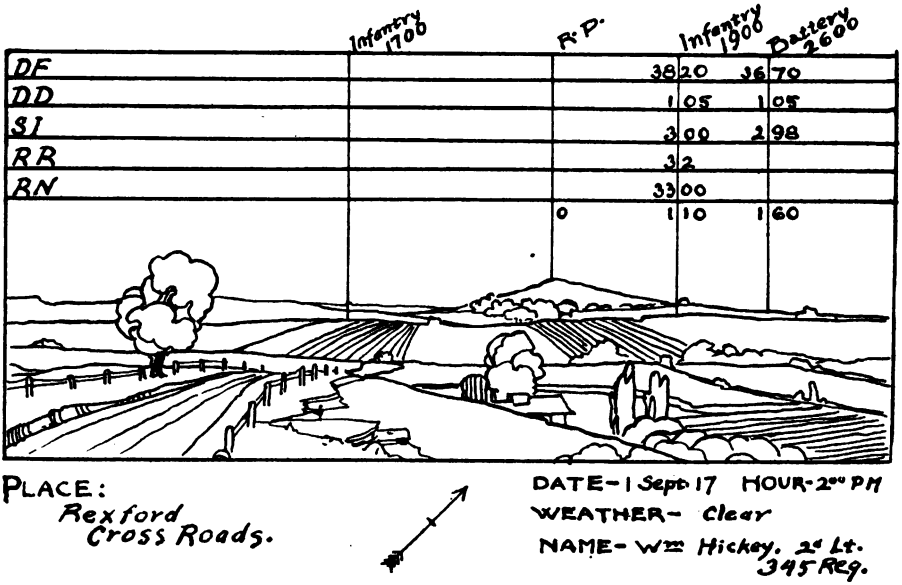

FIG. 49

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APPENDIX

SUGGESTIONS FOR INSTRUCTION AT TRAINING CAMPS

The author has had considerable experience in instruction pertaining to this subject at training camps, and the following suggestions may prove of some value to those upon whom this duty may fall in the future.

With the intensified course of training pursued at training camps, the time usually allotted to this subject is very limited, possibly not more than a half dozen periods of two hours each, so that it is a foregone conclusion that the instructor must work against time throughout the course. Another handicap is the limited number of instructors proportionate to those undergoing instruction, but, regardless of these serious disadvantages, much may be accomplished if the right methods are pursued.

Let us first consider the necessary preparations to be made by the instructor previous to the first instruction period. Aside from the authorized text-book, the student will require the following articles:

1. Drawing board with slope board attachment.
2. Compass.
3. Triangular ruler.
4. Pencil, Faber's HB.
5. Eraser.
6. Four thumb tacks.
7. Drawing paper.

Drawing Board

With large classes it is obvious that it would not be practicable to provide Engineer drawing boards. The tripod, although a convenience for the beginner, is not essential. The following plan proved successful at the Plattsburg Training Camps of 1915: purchase a sufficient amount of soft pine material 12″ by 1″ and saw into boards about a foot square. The drawing board may be suspended around the neck by

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means of a strong cord attached to the sides of the board in such a manner as to hold it in a horizontal position at the proper height for sketching.

COMPASS

Write to the Keuffel & Esser Cmpany, or any other reliable dealer, for samples, and select some good round compass that may be set into the drawing board by means of boring a hole of the same diameter as the compass, and of a sufficient depth to make the top of the compass flush with the surface of the board. By purchasing the compasses in lot, a considerable reduction may be obtained.

ATTACHMENT FOR READING SLOPES

With the many duties incident to training camp life, the men will not have the time nor the paraphernalia for constructing the slope board attachment. These should be placed on the boards before the camp begins. (See Fig. 11.) The process is simple, and with the aid of a few trained enlisted men, the work can soon be accomplished.

TRIANGULAR RULER

Go to some plaining mill and secure a sufficient number of triangular rulers similar to one shown in Fig. 2. Only the plain triangular pieces 6 inches long need be obtained.

PENCILS, ERASERS, THUMB TACKS, AND PAPER

These articles should all be secured in advance by the camp exchange officer. The Faber HB pencil is recommended, or any other pencil of about the same degree of hardness. As to the paper, transparent sheets may be obtained at a reasonable rate. This class of paper is of advantage as the rain will not affect it to any great extent, and prints may be made directly from the field sketches; however, for instruction purposes, the ordinary sheets of drawing paper will answer the purpose.

Do not fail to have the equipment as outlined ready for issue at the first period of instruction or previous to that time. The cost of the entire equipment as given above will not amount to

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much. The compass will be the largest item, but, as a matter of fact, it is a very essential part of a soldier's equipment. Possibly, funds allotted for training camp purposes may be available, especially for the drawing boards and the labor in connection with the attachment for reading angles of slope.

Do not attempt to have several work at the same drawing board. The plan has not proven successful. One or two will do the work and the remaining men will accomplish little. Each must do the work individually.

FIRST PERIOD

This period may be employed as follows: Having assembled the class a conference may be held involving the principles outlined in Lessons I and II, also pointing out the necessity of being able to make a sketch and read a military map. Then take the entire class to the target range, if one is available; if not, then to some suitable course previously measured, and let each man determine the length of his pace or stride as described in Lesson I. When this has been done, without doubt the time allotted will have been used up, and the class mat be dismissed with instructions to inscribe on their triangular ruler, aided by Figs. 2 and 3, a working scale of paces or strides for 3″ equals one mile and 6″ equals one mile. The following text references for the second period should also be given out: Lessons VI and XI. There will probably be very little time for any preparation, but those who do find a few minutes to read over the text references for the following day will be in a more receptive mood to grasp the practical work.

SECOND PERIOD

Explain by the aid of the blackboard the following basic principles of sketching: orientation, distance, direction, intersection, resection, and conventional signs. Students may consult the text freely regarding the latter until they become familiar with the various signs. Then assign some short, irregular course, not over a mile and a half in length, and, if practicable, a closed course. With a large class it will be found better to divide the class into sections, appointing such

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assistants as you may have in charge of the various sections. and prescribing several courses. Many members of the camp will be found to be experienced engineers, although not familiar with the hasty sketching methods followed out in the army. Such men should be distributed among the various sections, as they naturally acquire a knowledge of the work more readily and will render valuable assistance in helping the less fortunate over difficulties.

THIRD PERIOD

Relief Map and Contours

Before the opening of the camp, secure a sufficient amount of moulder's wax and construct a relief map similar to the one shown in Fig. 9, exhibiting the original map along with the relief map. These maps may be displayed in a vertical and elevated position at the conference, and the nature and object of contours explained therefrom.

Following this explanation, mimeographed copies of Fig. 14 or some similar illustration should be issued to the class, and each member should be required to interpolate the contours. In other words, impress on the student's mind the importance of first outlining the drainage.

An explanation of the auxiliary scale of elevations shown in Fig. 13 and its use should be given. Each man should place this scale for 3″ and 6″ equals one mile on his triangular working scale. Fig. 13 is a correct scale of elevations for 3″ equals one mile. By using every other division, a scale of elevations for 6″ equals one mile may be constructed. Also explain the use of the slope-board. This entire period is devoted to conference. Text reference for following period: read over Lesson XII.

FOURTH PERIOD

Road Sketch

Pick out about one and a half miles of road, preferably with as much relief as possible. If practicable, select several routes so that the roads will not be too congested with sketchers. Text reference for following period: read over Lesson XIII.

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FIFTH PERIOD

Position and Outpost Sketch

Select several areas of about half of a square mile, and assign sections to their tasks, first explaining basic principles as outlined in Lesson XIII.

Text reference for following period: read over Lesson XIV.

SIXTH PERIOD

Place Sketch

Deploy the entire class along some crest, and require each to sketch a prescribed sector, first explaining basic principles as outlined in Lesson XIV.

It was found at the Plattsburg Training Camps that, after a course of six periods as outlined above, nearly every man was able to turn in very creditable road, position, and place sketches. Their idea of drainage was good, and, along with the practical work, they had automatically learned much about reading a military map.

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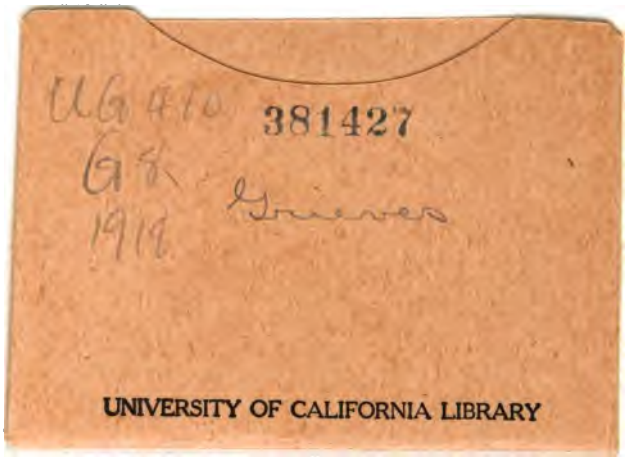

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